Chapter 6
Industry, Technology, and Competitiveness in the Marketplace

Contents

Highlights 6-2

Introduction 6-4
Chapter Background 6-4
Chapter Organization 6-4

U.S. Technology in the Marketplace 6-4
Comparing National Efforts at Technology Foresight 6-6
The Importance of High-Technology Industries 6-6
High-Tech Industries Continue to Show Higher Value Added Than Other Manufacturing Industries 6-8
Share of World Markets 6-9
Global Competitiveness of Individual Industries 6-10
Exports by High-Tech Industries 6-10
Competition in the Home Market 6-12
U.S. Trade Balance 6-12
U.S. Royalties and Fees Generated From Intellectual Property 6-14

International Trends in Industrial R&D 6-16
Overall Trends 6-16
R&D Performance by Industry 6-16

Patented Inventions 6-18
U.S. Patenting 6-18
Patents Granted to U.S. Inventors 6-18
Top Patenting Corporations 6-19
Patents Granted to Foreign Inventors 6-19
Private Use of Public Science 6-20
Technical Fields Favored by Foreign Inventors 6-21
Patenting Outside the United States 6-22
International Patenting Trends for Three Important Technologies 6-23
International Patent Families as a Basis for Comparison 6-23

Venture Capital and High-Technology Enterprise 6-30
U.S. Venture Capital Industry 6-30
Venture Capital Commitments and Disbursements 6-31
Venture Capital Investments by Stage of Financing 6-31
Europe's Venture Capital Industry 6-32

New High-Tech Exporters 6-33
National Orientation 6-34
Socioeconomic Infrastructure 6-34
Technological Infrastructure 6-35
Productive Capacity 6-36

Summary: Assessment of U.S. Technological Competitiveness 6-36

References 6-36

Highlights

International Economic Comparisons

- **The U.S. economy continues to rank as the world's largest, and Americans continue to enjoy one of the world's higher standards of living.** Japan's economy was less than 18 percent of the U.S. economy in 1960 and trailed several European economies. By 1970, it had grown to be the world's second largest economy, and in 1989, Japan had a gross domestic product (GDP) almost twice that of Germany and equal to nearly 40 percent of U.S. GDP.

- **Comparisons of general levels of labor productivity, measured by GDP per employed person, again show that other parts of the world are quickly closing in on the U.S. lead position.** For over 40 years, labor productivity growth in the United States generally trailed that in other countries. In 1960, U.S. GDP per employed person was twice that calculated for most European nations and four times that calculated for Japan. As of 1995, the gap has closed significantly, with labor productivity rates in many European nations nearly equal to that achieved in the United States. Productivity growth in Japan appears to have slowed down some since the early 1990s.

U.S. Technology in the Marketplace

- **The United States continues to be the leading producer of high-tech products, responsible for about one-third of the world's production.** While its margin of leadership narrowed during the 1980s when Japan rapidly enhanced its stature in high-tech fields, by 1995 U.S. high-tech industries regained world market share lost during the previous decade.

- **The market competitiveness of individual U.S. high-tech industries varies, although each of the industries maintained strong—if not commanding—market positions over the 15-year period examined.** Three of the four science-based industries that form the high-tech group (computers, pharmaceuticals, and communications equipment) gained market share in the 1990s. The aircraft industry was the only U.S. high-tech industry to lose market share from 1990 to 1995.

- **U.S. trade in technology products accounts for a much larger share of U.S. exports than U.S. imports; it therefore makes a positive contribution to the U.S. overall balance of trade.** After several years in which the surplus generated by trade in technology products declined, preliminary data for 1996 show a larger surplus than in 1995. Between 1990 and 1995, the U.S. trade surplus in software technology doubled. During that same period, trade in aerospace technologies consistently produced large—albeit declining—trade surpluses for the United States.

- **The United States is also a net exporter of technological know-how sold as intellectual property.** Royalties and fees received from foreign firms have been, on average, three times those paid out to foreigners by U.S. firms for access to their technology. U.S. receipts from licensing of technological know-how to foreigners exceeded $3.3 billion in 1995, up from $3.0 billion in 1994. Japan is the largest consumer of U.S. technology sold as intellectual property; South Korea is the second largest customer.

International Trends in Industrial R&D

- **Despite a two-decade decline in its international share of industrial research and development (R&D), the United States remains the world's leading performer of industrial R&D by a wide margin.** After 1990, the U.S. share stabilized at 46 percent of total industrial R&D performed by Organisation for Economic Co-operation and Development (OECD) countries. By comparison, the European Union accounted for 30 percent of the total industrial R&D performed by OECD countries during 1990-94; Japan accounted for about 20 percent. Preliminary 1995 data indicate a 1 percentage point rise in U.S. share, a 1 percentage point decline for Japan, and no change for the European Union.

- **The latest internationally comparable data on industry-level U.S. industrial R&D performance show the service sector's share rising from 4 percent in 1982 to 24 percent by 1992.** U.S. service sector industries, such as those developing computer software and providing communication services, have led the increase in R&D performance within the U.S. service sector. In 1994, this sector's share of total dropped to around 20 percent. Nevertheless, it still accounts for a larger share of U.S. industrial R&D performance than either the aerospace industry (11.9 percent of total) or the automobile industry (11.2 percent)—the top two R&D-performing industries in the U.S. manufacturing sector in 1994.

Patented Inventions

- **In 1994, for the first time ever, more than 100,000 patents were issued in the United States.** This record number of new patented inventions caps off what had been several years of steady increases that began in 1991. In 1995, the number of new U.S. patents granted again topped 100,000, with the final count reaching 101,419. U.S. inventors received 55 percent of the patents granted in 1995; this continues a general upward trend in the proportion of new patents granted to U.S. inventors that began in the late 1980s.

- **Foreign patenting in the United States continues to be highly concentrated by country of origin.** In 1995, two countries—Japan and Germany—accounted for over 60 percent of foreign-origin U.S. patents. The top five countries—Japan, Germany, France, the United Kingdom, and Canada—accounted for 80 percent. Several of the newly industrialized economies, notably Taiwan and South Korea, have dramatically increased their patent activity since the late 1980s.

- **Recent patent emphases by foreign inventors in the United States show widespread international focus on several commercially important technologies.** Japanese inventors tend to concentrate their U.S. patenting in consumer electronics, photography, photocopying, and—more recently—computer technologies. German inventors continue to develop new products and processes in technology areas associated with heavy manufacturing industries. Inventors from Taiwan and South Korea are earning an increasing number of U.S. patents in communications and computer technologies.

- **Americans successfully patent their inventions around the world.** U.S. inventors received more patents than other foreign inventors in neighboring countries (Canada and Mexico) and in distant markets such as Japan, Hong Kong, Brazil, India, Malaysia, and Thailand.

- **International patenting in three important technologies—robot technology, genetic engineering, and advanced ceramics—underscores the inventive activity by the United States, Japan, and Europe.** Based on an examination of national patenting in 33 countries during the 1990-94 period, Japan and the United States lead in overall technological activity in these areas. Although South Korea's share of international patent families was lowest overall for the countries examined, it made an impressive showing in each of the technology areas.

Venture Capital and High-Technology Enterprise

- **The pool of venture capital managed by U.S. venture capital firms grew dramatically during the 1980s as venture capital emerged as an important source of financing for small innovative firms.** In the 1990s, the venture capital industry experienced a "recession" of sorts as investor interest waned and the amount of venture capital disbursed declined. But this slowdown was short-lived: investor interest picked up in 1992, and disbursements began to rise again.

- **Software companies attracted more venture capital than any other technology area.** In 1995, venture capital firms disbursed a total of $3.9 billion, of which 20 percent went to firms developing computer software or providing software services. Medical and health-related companies were second with 14 percent.

- **Very little venture capital actually goes to the struggling inventor or entrepreneur as "seed" money.** Over the past 10 years, money given to prove a concept or for early product development never accounted for more than 7 percent of total venture capital disbursements and most often represented 3 to 4 percent of the annual totals. In 1995, seed money accounted for 6 percent of all venture capital disbursements, while money for company expansion garnered 42 percent.

- **As in the United States, venture capitalists in Europe are attracted to young, small, fast-growing companies in need of capital and management expertise.** Europe now has venture-capital-backed investments all across the continent, including investments in many of the transitioning countries in Central and Eastern Europe.

- **While computer-related and biotechnology companies in the United States garner the lion's share of U.S. venture capital, the types of firms attracting venture capital in Europe are less technology intensive.** Europe has long held a reputation for excellence in industrial machinery and equipment, fashion, and leisure products (e.g., sporting goods). These same industries are among the top recipients of European venture capital.

- **European venture capitalists, like their American counterparts, direct only a small portion of capital disbursements as seed money or startup capital.** Investments for expanding an existing company's productive capacity, helping a company add a new product line, or enabling a company to acquire an existing business—later stage investments—account for about 85 percent of European venture capital disbursements.

New High-Tech Exporters

- **Several Asian economies seem headed toward future prominence as technology developers and a greater presence in global high-tech product markets,** when a model of leading indicators is applied. Taiwan and South Korea seem best positioned to enhance their stature in technology-related fields and their competitiveness in high-tech markets. Malaysia and the Philippines scored surprisingly well in many areas and could be the next Asian "tigers," although the model suggests that their technological foundations are still less developed and narrower than those found in either Taiwan or South Korea. Recently, several Asian nations have faced turmoil in their banking systems and capital markets. It is unclear how these developments will affect Asian economies and their science and technology capabilities.

Introduction

Chapter Background

A nation's competitiveness is often judged by its ability to produce goods that find demand in the international marketplace while simultaneously maintaining—if not improving—the standard of living of its citizens (OECD 1996). Science and engineering (S&E), and the technological developments that emerge from S&E activities, enable high-wage nations like the United States to compete alongside low-wage countries in today's increasingly global marketplace. Although the U.S. economy continues to rank as the world's largest, and Americans continue to enjoy one of the world's higher standards of living, many other parts of the world are closing the gap. (See figure 6-1 and appendix tables 6-1, 6-2, and 6-3.)

This chapter highlights the unique role played by industry within the nation's science and technology (S&T) enterprise as it develops, uses, and commercializes investments in S&T made by industry, academia, and government. Within the chapter, indicators or proxies identify trends that provide measurements of industry's part in the nation's S&T enterprise and, wherever possible, place U.S. activity and standing in the more science-based industries in a global context.

Chapter Organization

This chapter begins with a review of the market competitiveness of industries that rely heavily on research and development (R&D); these are often referred to as high-technology industries.[1] The importance of high-tech industries is linked to their high R&D spending and performance which produce innovations that spill over into other economic sectors; additionally, these industries help train new scientists, engineers, and other technical personnel (see Nadiri 1993 and Tyson 1992). The market competitiveness of a nation's technological advances, as embodied in new products and processes associated with these industries, can also serve as an indicator of the effectiveness of that country's S&T enterprise. The marketplace provides a relevant economic evaluation of a country's use of science and technology.

U.S. high-tech industry competitiveness is assessed through an examination of market share trends worldwide, at home, and in various regions of the world. New data on royalties and fees generated from U.S. imports and exports of technological know-how are used to gauge U.S. competitiveness when technological know-how is sold or rented as intangible (intellectual) property.

The chapter explores several leading indicators of technology development (1) via an examination of changing emphases in industrial R&D among the major industrialized countries and (2) through an extensive analysis of patenting trends. New information on international patenting trends of U.S. foreign inventors in several important technologies is presented.

The chapter also presents information on trends in venture capital disbursements. Venture capital is an important source of funds used in the formation and expansion of small high-tech companies. This section examines venture capital disbursements by stage of financing and by technology area in the United States and in Europe.

The chapter concludes with a presentation of leading indicators that are designed to identify those developing and transitioning countries with the potential to become more important exporters of high-technology products over the next 15 years.

U.S. Technology in the Marketplace

Most countries in the world acknowledge a symbiotic relationship between national investments in S&T and competitiveness in the marketplace: science and technology support business competitiveness in international trade, and commercial success in the global marketplace provides the resources needed to support new science and technology. Consequently, the health of the nation's economy becomes a performance measure for the national investment in R&D and in science and engineering. (See "Comparing National Efforts at Technology Foresight.")

This section discusses U.S. "competitiveness," broadly defined here as the ability of U.S. firms to sell products in the international marketplace. A great deal of attention is given to science-based industries producing products that embody above-average levels of R&D in their development (hereafter referred to as *high-tech industries*). The Organisation for Economic Co-operation and Development (OECD) currently identifies four industries as high-tech based on their high R&D intensities: aerospace, computers and office machinery, electronics-communications, and pharmaceuticals.[2]

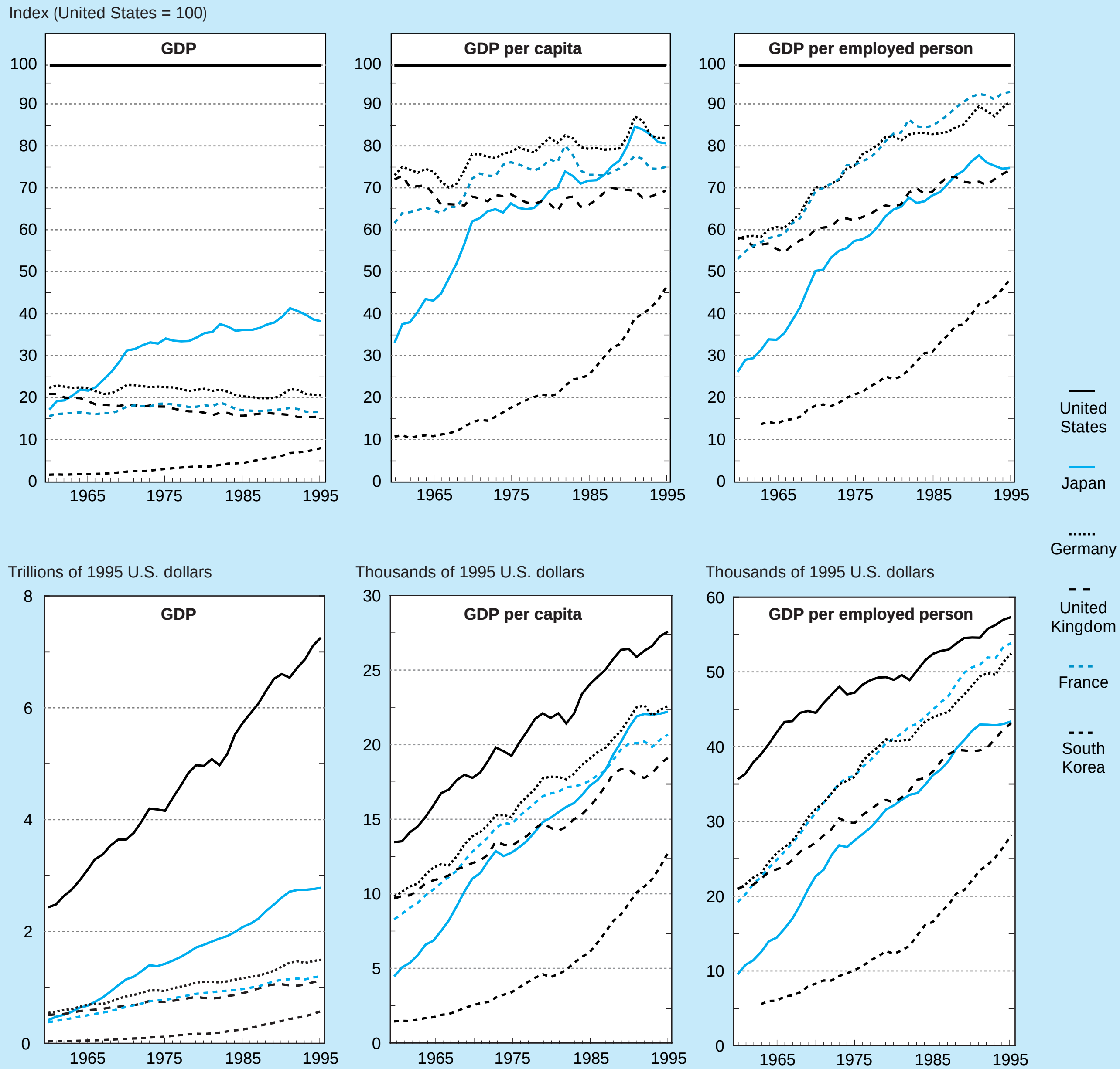
There are several reasons why high-tech industries are important to nations.

- ♦ High-tech firms are associated with innovation. Firms that

[1] In this chapter, high-tech industries are identified using R&D intensities calculated by the Organisation for Economic Co-operation and Development. There is no single preferred methodology for identifying high-technology industries. The identification of those industries considered to be high-tech has generally relied on a calculation comparing R&D intensities. R&D intensity, in turn, has typically been determined by comparing industry R&D expenditures and/or numbers of technical people employed (i.e., scientists, engineers, technicians) to industry value added or to the total value of its shipments.

[2] In designating these high-tech industries, OECD took into account both direct and indirect R&D intensities for 10 countries: the United States, Japan, Germany, France, the United Kingdom, Canada, Italy, the Netherlands, Denmark, and Australia. Direct intensities were calculated by the ratio of R&D expenditure to output (production) in 22 industrial sectors. Each sector was given a weight according to its share in the total output of the 10 countries using purchasing power parities as exchange rates. Indirect intensity calculations were made using technical coefficients of industries on the basis of input-output matrices. OECD then assumed that for a given type of input and for all groups of products, the proportions of R&D expenditure embodied in value added remained constant. The input-output coefficients were then multiplied by the direct R&D intensities. For further details concerning the methodology used, see OECD (1993).

Figure 6-1.
International economic comparisons



NOTE: Country GDPs were determined with 1993 purchasing power parities using the Elteto-Köves-Szulc (EKS) aggregation method and 1995 U.S. dollars.

See appendix tables 6-1, 6-2, and 6-3.

Science & Engineering Indicators – 1998

innovate tend to gain market share, create new product markets, and/or use resources more productively (NRC 1996 and Tassey 1995).

- High-tech firms are associated with high value-added production and success in foreign markets, which helps to support higher compensation to the workers they employ. (See “High-Tech Industries Continue to Show Higher Value Added Than Other Manufacturing Industries.”)

- Industrial R&D performed by high-tech industries has other spillover effects. These effects benefit other commercial sectors by generating new products and processes that can often lead to productivity gains, business expansions, and the creation of high-wage jobs (Nadiri 1993, Tyson 1992, and Mansfield 1991).

Comparing National Efforts at Technology Foresight

Technology foresight is a tool used by many nations in the S&T priority-setting process. It can be defined as a systematic process for looking into the future to identify important technologies for the purpose of aiding in policy formation, planning, and decisionmaking. Most of the national technology foresight exercises conducted in recent years have involved the administration of a Delphi survey or the generation of a list of critical technologies. Whatever the methodology used, the findings of most of these exercises have included the identification of important technologies and an assessment of relative national position in those technologies identified as important.

The *Delphi survey approach* to technology foresight attempts to forecast technological developments over the long-term (20- to 30-year) future. First developed by the RAND Corporation in the 1950s, Delphi survey techniques have been used for technology foresight purposes in Japan since 1971 and in Germany, France, and the United Kingdom over the past decade. In the Delphi process, many experts receive two or more rounds of surveys in which they are asked to respond to a detailed questionnaire covering different technological developments. The technological developments themselves are not considered to be inherently important; they are only the starting points on which the survey is based. Respondents are asked to rate each development on several measures, including degree of importance for factors such as wealth creation or quality of life and expected date of realization. Respondents are also asked to rate the relative position of different countries in each technological development, based on a certain criterion such as level of R&D activity. Between survey rounds, the experts receive a summary of all responses to allow them to reconsider their assessments in light of those provided by their peers.

The *critical technologies approach* involves the generation of a list of technologies deemed critical for a country's future. Most lists also provide assessments, based on expert opinion, of relative national position in those technologies identified as critical. In recent years, critical technologies lists have been developed in the United States, Germany, and France. The definition of critical, the criteria for determining criticality, and the criteria for making assessments of national position vary by study. Among the factors considered in different studies are the importance for economic competitiveness, effect on the environment, relevance for national security, and contribution to the quality of life. Critical technologies are sometimes defined as those that are generic, or "precompetitive," and that have the potential for application in many industrial sectors. Lists of critical technologies are usually developed using a time frame of about 10 years.

Across these different types of national foresight studies, there is some agreement about which categories are useful for classifying important future technologies. The broad technological categories considered important in most studies include biotechnology and life sciences, energy, environment, transportation, information and communications, manufacturing processes, management and business, and materials.

Nations have designated different subfields within these broad technological categories as important to them; this complicates further attempts at comparing the various national technology assessments. Some technologies, however, have been identified by several studies as important; these include advanced ceramics, nanotechnology, biocompatible materials, nuclear waste storage, broadband communications, optical technology, catalysis, renewable energy, flat display technology, semiconductors, intelligent transportation systems, and signal processing.

Besides identifying important technologies and the categories under which these can be classified, most foresight exercises also address the issue of national position in important S&T fields. Self-assessments of relative position are made at both the category and individual technology levels. However, these assessments are difficult to compare across countries because they use different methodologies, criteria, and measures. (See text table 6-1.)

The Importance of High-Technology Industries

The global market for high-tech goods is growing at a faster rate than that for other manufactured goods, and economic activity in high-tech industries is driving national economic growth around the world.[3] Over the 15-year period examined (1980-95), high-tech production grew at an inflation-adjusted average annual rate of nearly 6 percent compared with a rate of 2.4 percent for other manufactured goods.[4] Global economic activity was especially strong at the end of the period (1993-95), when high-tech industry output grew at over 8 percent per year—more than twice the rate of growth for all

[3]The WEFA/ICF Global Industry Model database reports production data by 68 countries and accounts for over 97 percent of global economic activity.

[4]Service sector industries grew at an average annual inflation-adjusted rate of 3.3 percent during this period.

Text table 6-1.
Comparison of assessments of relative technological position in international foresight exercises

	U.S. critical technologies	Japanese Delphi	German Delphi	French Delphi	U.K. Delphi	French critical technologies	German critical technologies	Australia foresight study
Type of position assessed	Technological position	R&D level	R&D leadership	R&D leadership	S&T capability *(also innovation capacity, production capability or service delivery, and exploitation and commercia-lization potential)*	Scientific position *(also industrial position)*	Competitive position	Share of international scientific publications and citations
Countries compared	U.S., Japan, and Europe[a]	Japan, "other countries"	Germany, Japan, U.S., "other countries"	France, Germany, Japan, U.S.[b]	United Kingdom	France[c]	Germany	Australia
Measurement scale used	U.S. has a substantial lead U.S. has a slight lead U.S. is on par U.S. slightly lags U.S. substan-tially lags	Measured as mean percentage of respondents, across topics, saying that: Japan is more advanced Japan is equivalent to other countries Other countries are more advanced	Measured as mean percentage of respondents, across topics, saying that: Germany is the leader Japan is the leader U.S. is the leader Other countries are leaders	Measured as mean percentage of respondents, across topics, saying that: France is the leader Germany is the leader Japan is the leader U.S. is the leader	Measured as mean percentage of respondents, across topics, saying that the: U.K. is at leading edge U.K. is an average performer U.K. is lagging behind	Strong Moderate Weak Nonexistent	Strong Average Limited	Position assessed relative to other scientific areas and interpreted as: Strong Average Weak

NOTES: Foresight reports are from the following sources: **U.S.—**U.S. Office of Science and Technology Policy (U.S. OSTP) *National Critical Technologies Report* (Washington, DC: National Critical Technologies Panel, 1995); **Japanese—**National Institute of Science and Technology Policy (NISTP), *The Fifth Technology Forecast Survey—Future Technology in Japan*, NISTP Report No. 25 (Tokyo: Science and Technology Agency, 1992); **German Delphi—**NISTP and Fraunhofer Institute for Systems and Innovation Research, *Outlook for Japanese and German Future Technology: Comparing Japanese and German Technology Forecast Surveys*, NISTP Report No. 33 (Tokyo: Science and Technology Agency, 1994); **French Delphi—**Ministère de l'Enseignement Supérieur et de la Recherche, *Enquête sur les Technologies du Futur par la Méthode Delphi: Présentation des Résultats Synthèse et Commentaires* (Strasbourg: BETA, CNRS, Université Louis Pasteur, 1995) [note that this report was not completely accepted by the French Government because of methodological concerns]; **U.K.—**D. Loveridge, L. Georghiou, and M. Nedeva, *United Kingdom Technology Foresight Programme: Delphi Survey* (London: HMSO, 1995); **French critical technologies—**Ministère de l'Industrie, *Les Technologies Clés pour l'Industries Française à l'Horizon 2000* (Paris: 1995); **German critical technologies—**H. Grupp, "Technology at the Beginning of the 21st Century," *Technology Analysis and Strategic Management*, Vol. 6, No. 4: 379-409; and **Australian—**ASTEC, *Developing Long-Term Strategies for Science and Technology in Australia: Findings of the Study Matching Science and Technology to Future Needs 2010* (Canberra: AGPS, 1996).

[a]Europe's position is "treated as an aggregate and assessments are based on the best demonstrated capability in any European country rather than on average across countries"(U.S. OSTP 1995, p. 191).

[b]The French Delphi also gave respondents the choice of "other countries," but the report did not include those responses in all calculations for methodological reasons.

[c]The French critical technologies report also assessed the scientific and industrial positions of Europe.

SOURCE: Based on the analysis and synthesis of national technology foresight reports in Mogee Research & Analysis Associates, "SGER: Comparing Assessments of National Position in Key Science & Technology Fields," report prepared under National Science Foundation SGER Grant No. SRS-9618668 (Washington, DC: 1997).

Science & Engineering Indicators – 1998

other manufacturing industries. (See figure 6-2 and appendix table 6-5.) Output by the four high-tech industries—those identified as being the most research intensive—represented 7.6 percent of global production of all manufactured goods in 1980; by 1995, this output represented 12 percent.

During the 1980s, the United States and other high-wage countries increasingly moved resources toward the manufacture of technology-intensive goods. In 1989, U.S. high-tech manufactures represented nearly 13 percent of total U.S. production of manufactured output, up from 10.4 percent in 1980. High-tech manufactures also accounted for growing shares of total production for European nations, but the transition to high tech in Europe during the 1980s was most prominent in the United Kingdom's economy. High-tech manufactures represented just 9 percent of the United Kingdom's total manufacturing output in 1980, but jumped to 13 percent by 1989. The Japanese economy led all other major industrialized countries in its concentration on high-tech industries. In 1980, high-

High-Tech Industries Continue to Show Higher Value Added Than Other Manufacturing Industries

By definition, the concept of manufacturing value added seeks to measure the contribution of manufacturing activity to a nation's economy (as measured by gross domestic product). (See Greenwald and Associates 1984 and Pearce 1983.) At the firm level, the measurement nets out (removes) from the value of the final output the value of purchased inputs to the production process. At the national level, the measurement nets out foreign-supplied inputs from the value of the nation's final output—thereby determining domestic content of production for an industry or set of industries.

New data from OECD permit comparison of domestic content in high-tech industries and all other manufacturing industries for several countries. Examination of these data shows that high-tech industries continue to incorporate more domestic content in their manufacturing operations than do other manufacturing industries; this trend, however, is not consistent for all countries nor necessarily true for each of the four high-tech industries (i.e., aircraft, communications, office and computers, drugs and medicines). (See text table 6-2.) For example, about 43 percent of the final output by U.S. high-tech industry in 1993 is attributed to domestic value added, compared with 35 percent in all other U.S. manufacturing industries. The difference in value added as a proportion of final output between these two sectors was much larger in Germany and much less in Japan.

Within each country, trends for individual high-tech industries varied. The U.S. drugs and medicines industry, at 56 percent, had the highest ratio of value added among the four U.S. high-tech industries in 1993; the computer/office hardware industry showed lower value added in its U.S. manufacturing operations (about 28 percent) than the average for all other manufacturing. The relative value-added profile for Japan's high-tech industries was similar to that of the United States.

The impact of the global economy is also apparent from an examination of these data. In high-wage countries like the United States and Germany, domestic content in manufacturing industries fell between 1973 and 1993, while domestic content rose in lower wage countries such as South Korea and Spain. (See appendix table 6-4.)

Text table 6-2.
Proportion of manufacturing final output attributed to domestic content (value added/production)
(Percentages)

	1973	1983	1993
United States			
Total manufacturing	37.4	33.8	36.1
High-tech manufacturing	44.7	46.1	42.6
Aircraft	42.1	49.4	32.6
Communications	44.3	45.0	51.1
Office & computers	44.5	37.7	27.9
Drugs & medicines	54.2	54.2	56.4
Other manufacturing	36.8	32.3	35.1
Japan			
Total manufacturing	33.5	31.5	37.1
High-tech manufacturing	40.6	37.9	37.2
Aircraft	47.1	43.8	41.7
Communications	37.5	34.8	34.8
Office & computers	35.6	34.3	31.7
Drugs & medicines	58.7	58.0	61.8
Other manufacturing	32.9	30.7	37.1
Germany[a]			
Total manufacturing	37.4	35.9	37.1
High-tech manufacturing	52.4	54.5	48.9
Aircraft	45.8	39.0	42.7
Communications	50.0	53.3	48.0
Office & computers	83.1	76.4	55.4
Drugs & medicines	47.9	51.5	49.7
Other manufacturing	36.4	34.5	36.0

NA = not available

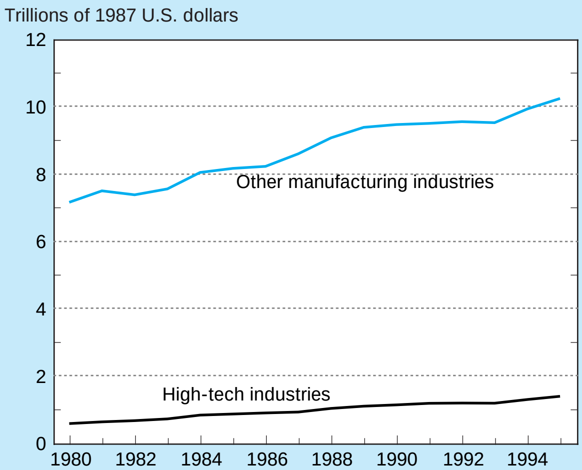
[a]Germany's data are for 1976, 1983, and 1992; data for all but 1992 are for West Germany only.

See appendix table 6-4. *Science & Engineering Indicators – 1998*

tech manufactures accounted for about 10 percent of total Japanese production, rose to 13 percent in 1984, and then increased to 15.3 percent in 1989.

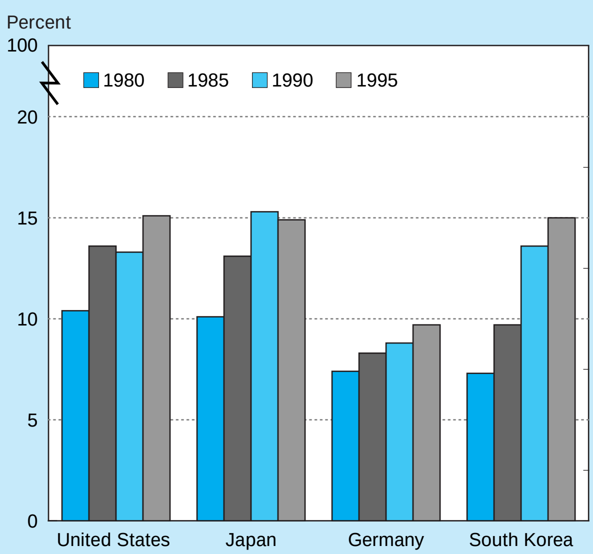
Data for the 1990s show an increased emphasis on high-tech manufactures among the major industrialized countries. (See figure 6-3.) In 1995, high-tech manufactures are estimated to represent 15 percent of manufacturing output in both the United States and Japan, 14 percent in the United Kingdom, and 10 percent each in France and Germany. Two other Asian countries, China and South Korea, typify how important R&D-intensive industries have become to the newly industrialized economies. In 1980, high-tech manufactures accounted for just 4 percent of China's total manufacturing output; this proportion jumped to 11.4 percent in 1989 and then reached 12.5 percent in 1995—more than for France or Germany. In 1995, high-tech manufacturing in South Korea accounts for about the same percentage of total output as in Japan and the United States (15 percent).

Figure 6-2.
Global sales of manufactured products



See appendix table 6-5. *Science & Engineering Indicators – 1998*

Figure 6-3.
High-tech industries' share of total manufacturing output



See appendix table 6-5. *Science & Engineering Indicators – 1998*

Share of World Markets

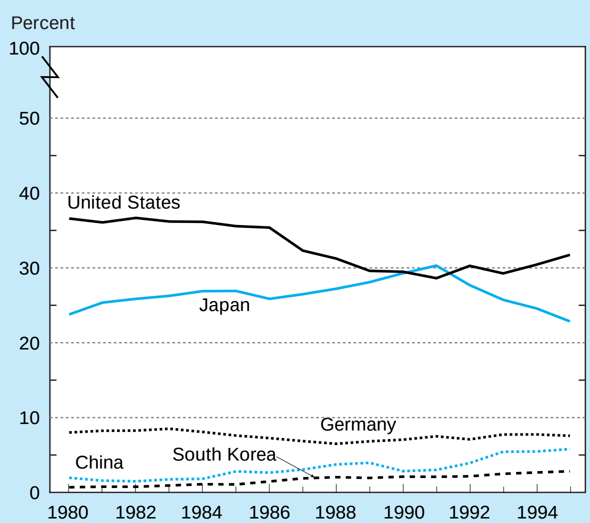
Throughout the 1980s, the United States was the leading producer of high-tech products, responsible for over one-third of total world production from 1980 to 1986, and for about 30 percent of world production for the rest of the decade. While U.S. world market share continued to decline into the early 1990s, the downward trend reversed in 1992. The U.S. share of the world market for high-tech manufactures grew irregularly after 1991. By 1995, U.S. high-tech industries had regained much of the market share lost during the previous decade. (See figure 6-4.) In 1995, production by U.S. high-tech industry accounted for nearly 32 percent of world high-tech production.

While U.S. high-tech industry struggled to maintain market share during the 1980s, the Japanese global market share in high-tech industries followed a path of steady gains. In 1989, Japan accounted for 28 percent of the world's production of high-tech products, moving up 4 percentage points since 1980. Japan continued to gain on the United States until 1991 when, for the first time, it moved past the United States to become the world's leading high-tech producer. Since then, however, Japan's market share has dropped steadily, falling to under 23 percent of world production in 1995 after accounting for more than 30 percent four years earlier.

By comparison, European nations' share of world high-tech production is much lower. Germany produced about 8 percent of world high-tech production in 1980, under 7 percent in 1989, and nearly 8 percent once again by 1995. Shares for both France and the United Kingdom fluctuated between 4 and 5 percent throughout the 15-year period examined.

China has made the most dramatic gains since 1980, although these gains were made in spurts. During the first half of the 1980s, China's market share moved downward, hovering around 2 percent of world high-tech production. By 1989, the country's share had doubled. After a one-year decline down to 2.9 percent in 1990, China's high-tech production increased significantly; by 1995, the country accounted for nearly 6 percent of world high-tech output.

Figure 6-4.
Country share of global high-tech market



NOTE: German data are for the former West Germany only.

See appendix table 6-5. *Science & Engineering Indicators – 1998*

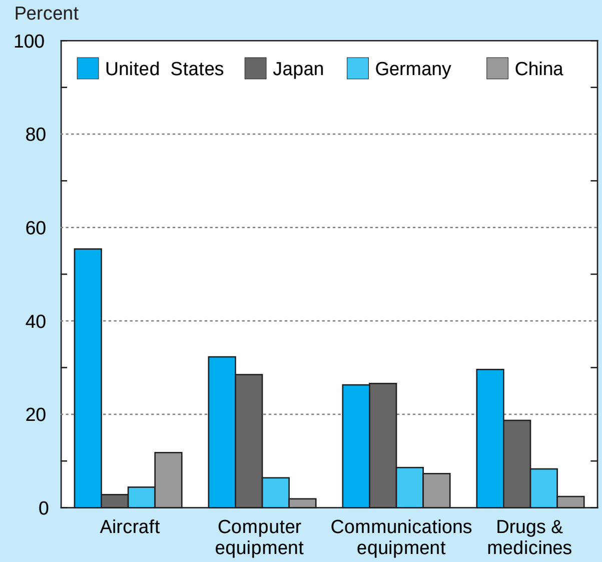
Global Competitiveness of Individual Industries

In each of the four industries that make up the high-tech group, the United States maintained strong, if not leading, market positions over the 15-year period examined. Yet competitive pressures from a growing cadre of high-tech-producing nations contributed to a decline in global market share for three U.S. high-tech industries during the 1980s: aircraft, computers, and communications equipment. Since then, two of these industries—computers and, in particular, communications equipment—have reversed their downward trends and gained market share in the 1990s. (See figure 6-5.)

The U.S. aircraft industry, the nation's strongest high-tech industry in terms of world market share, was the one high-tech industry to lose market share in the 1980s and again in the 1990s. For much of the 1980s, the U.S. aircraft industry supplied about two-thirds of world demand. Within the 1980-95 period, the U.S. share of the world aircraft market peaked in 1986, when it supplied over 66 percent of world demand; it then lost market share nearly every year since. By 1995, the U.S. share had fallen to 55 percent of the world market. (See figure 6-6.) While European aircraft industries gained market share during this time, Chinese industries made especially large gains in global market share beginning in 1992. In 1980, China supplied about 3.5 percent of world aircraft shipments; by 1995, its share had increased to nearly 12 percent.

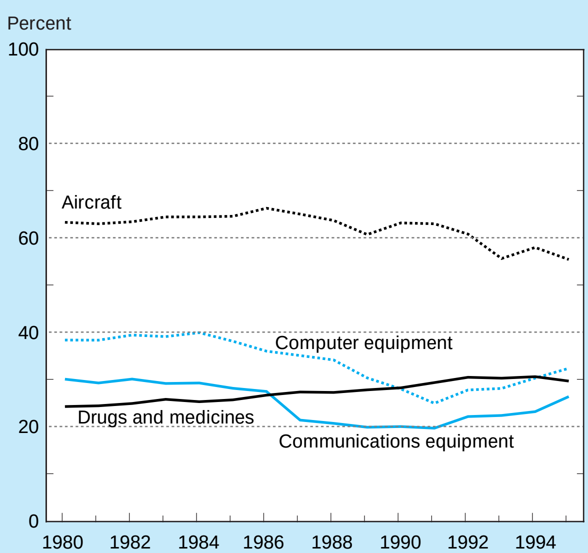
As previously noted, two U.S. high-tech industries lost market share during the 1980s and then reversed that trend during the 1990s. By 1995, the United States was the number one supplier of computer equipment in the world and in a virtual tie with Japan for number one in terms of worldwide shipments of communications equipment.

Figure 6-6.
Global market share, by country and high-tech industry: 1995



See appendix table 6-5. *Science & Engineering Indicators – 1998*

Figure 6-5.
U.S. global market share, by high-tech industry



See appendix table 6-5. *Science & Engineering Indicators – 1998*

Of the four high-tech industries, only the U.S. pharmaceutical industry managed to retain its number one ranking throughout the 15-year period. It was also the only U.S. high-tech industry that had a larger share of the global market in 1995 than in 1980.

The United States is considered a large, open market. These characteristics benefit U.S. high-tech producers in two important ways. First, supplying a market with many domestic consumers provides scale effects to U.S. producers in the form of potentially large rewards for the production of new ideas and innovations (Romer 1996). Second, the openness of the U.S. market to foreign-made technologies pressures U.S. producers to be inventive and to move toward more rapid innovation in order to maintain domestic market share.

This discussion of world market shares shows that U.S. producers are leading suppliers of high-tech products to the global market. That evaluation incorporates U.S. sales to domestic as well as foreign customers. In the next sections, these two markets are examined separately.

Exports by High-Tech Industries

While U.S. producers reaped many benefits from having the world's largest home market (as measured by gross domestic product—GDP), mounting trade deficits have led to concern about the need to expand U.S. exports. U.S. high-tech industries have traditionally been more successful than other U.S. industries in foreign markets. Consequently, high-tech industries have attracted considerable attention from policymakers as they seek ways to return the United States to a more balanced trade position.

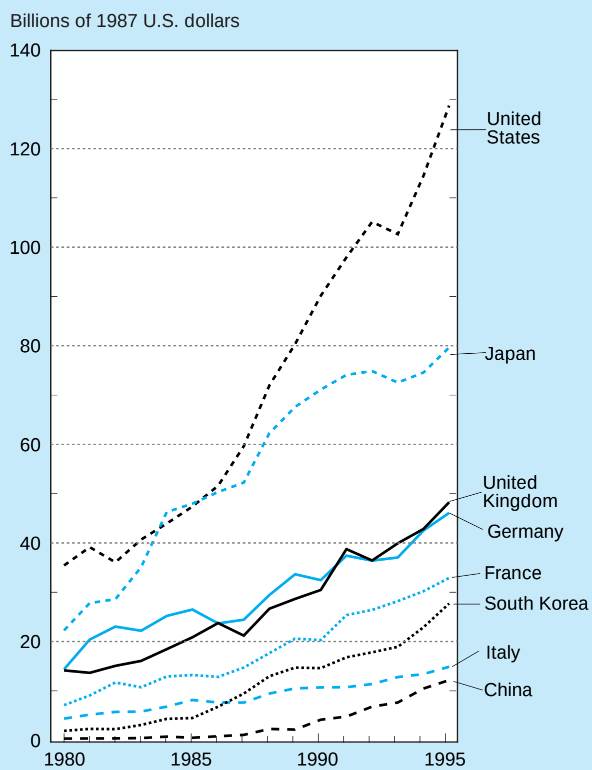
Foreign Markets

Despite its domestic focus, the United States has been an important supplier of manufactured products in foreign markets throughout the 1980-95 period. In fact, from 1992 to 1995, the United States was the leading nation exporter of manufactured goods, accounting for between 12.1 and 12.8 percent of world exports. U.S. high-tech industries have contributed to this strong export performance of the nation's manufacturing industries.

Over the same 15-year period, U.S. high-tech industries accounted for between 19 and 26 percent of world high-tech exports—at times twice the level achieved by all U.S. manufacturing industries. The peak was reached in 1980, and U.S. market share has fallen fairly consistently since then. In 1995, the latest year for which data are available, exports by U.S. high-tech industries accounted for 19.2 percent of world high-tech exports; Japan was second, accounting for 11.9 percent; followed by the United Kingdom and Germany, with 7.2 percent and 6.9 percent, respectively.

The drop in U.S. share over the 15-year period is in part the result of the emergence of high-tech industries in newly industrialized economies, especially within Asia. South Korea is one example. (See figure 6-7.) In 1980, high-tech industries in South Korea accounted for about 1.4 percent of world high-tech exports. That market share doubled by 1986. The latest data for 1995 show South Korea's share reaching 4.1 percent, nearly twice the market share of high-tech exports held by Italy that same year.

Figure 6-7.
High-tech exports



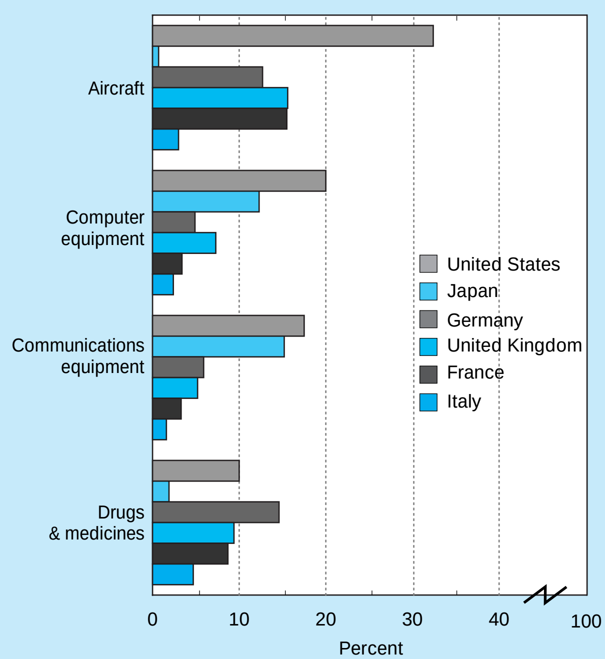
See appendix table 6-5. *Science & Engineering Indicators – 1998*

Industry Comparisons

Throughout the 15-year period, individual U.S. high-tech industries either led in exports or were second to the leader in each of the four industries included in the high-tech grouping. The most current data, 1995, show the United States as the export leader in three industries and second in just one—drugs and medicines. (See figure 6-8.) As noted in the previous section on global market shares, the U.S. pharmaceutical industry was the only U.S. high-tech industry that consistently led the world in production and that also had a larger share of the world market in 1995 than in 1980. Since global market shares incorporate all shipments—foreign and domestic—this industry's sales to the U.S. market appear to be responsible for its gain in world market share.

In terms of export performance, U.S. industries producing aircraft, computers, and pharmaceuticals all accounted for smaller export shares in 1995 than in 1980. The communications equipment industry was the sole U.S. high-tech industry to improve its share of world exports over the period. By

Figure 6-8.
Export market share: 1995



See appendix table 6-5. *Science & Engineering Indicators – 1998*

comparison, the share of world exports held by Japan's communications equipment industry dropped steadily after 1985—eventually falling to 15.2 percent by 1995 from a high of 36.5 percent just 10 years earlier. In addition to gains in world export share by the United States and the United Kingdom, once again the newly industrialized economies of Asia demonstrated an ability to produce high-tech goods to world-class standards and were rewarded with great success in selling to foreign markets. In 1995, South Korea supplied 6.8 percent of world communication product exports, up from just 2.7 percent in 1980. Other Asian newly industrialized economies have demonstrated similar capabilities in communications equipment.

Competition in the Home Market

A country's home market is often thought of as the natural destination for the goods and services produced by domestic firms. For obvious reasons—including proximity to the customer and common language, customs, and currency—marketing at home is easier than marketing abroad.

But with trade barriers falling and the number of foreign firms able to produce goods to world standards rising, product origin may only be one factor among many influencing the consumer's choice between competing products. Price, quality, and product performance often become equally important determinants guiding product selection. Thus, in the absence of trade barriers, the intensity of competition faced by domestic producers in their home market can approach—and, in some markets, may even exceed—the level of competition faced in foreign markets. Explanations for U.S. competitiveness in foreign markets may be found in the two dynamics of the U.S. market: the existence of tremendous domestic demand for the latest advanced technology products and the degree of world-class competition that continually pressures U.S. industry toward innovation and discovery.

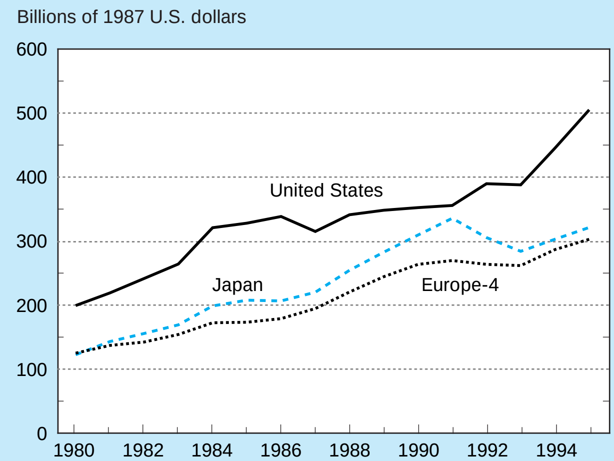
National Demand for High-Tech Products

Demand for high-tech products in the United States far exceeds that in any other single country and is larger than the combined markets of the four largest European nations (Germany, the United Kingdom, France, and Italy). (See figure 6-9.) This was consistently the case for the entire 1980-95 period. Japan, too, has large domestic demand for high-tech products, and was the second largest market for high-tech products in the world—its demand was much closer in size to that of the United States than to the next largest high-tech market, Germany.

National Producers Supplying the Home Market

Throughout the 1980-95 period, the world's largest market for high-tech products, the United States, was served primarily by domestic producers—yet demand was increasingly met by a growing number of foreign suppliers. (See figure 6-10.) In 1995, U.S. producers supplied about 73 percent of the home market for high-tech products (i.e., aerospace, computers, communications equipment, and pharmaceuticals); however, in 1980, U.S. producers' share was much higher, nearly 92 percent.

Figure 6-9.
Apparent consumption of high-tech products



NOTE: Europe-4 refers to the four largest European economies: Germany, France, the United Kingdom, and Italy.

See appendix table 6-5. *Science & Engineering Indicators – 1998*

Other countries have experienced similar increased foreign competition in their domestic markets. This is especially true in Europe. A more economically unified European market has had the effect of making Europe an even more attractive market to the rest of the world. Rapidly rising import penetration ratios in the four large European nations during the latter part of the 1980s and throughout the first half of the 1990s reflect these changing circumstances. These data also highlight greater trade activity in European high-tech markets when compared with product markets for less technology-intensive manufactures.

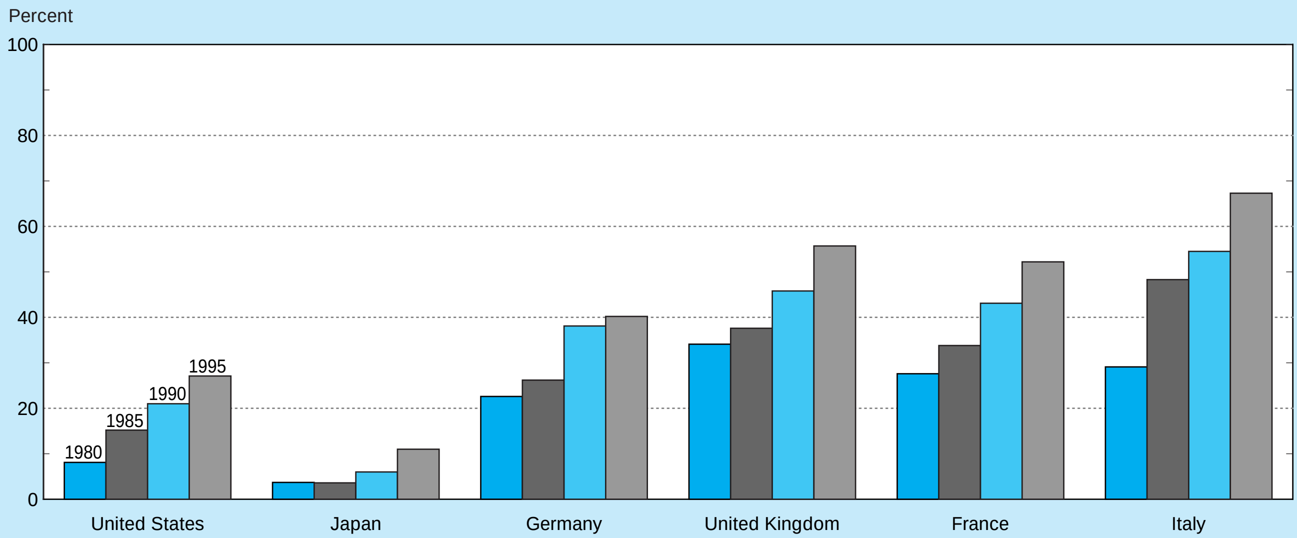
The Japanese home market, the second largest national market for high-tech products and historically the most self-reliant of the major industrialized countries, also increased its purchases of foreign technologies over the 15-year period, albeit slowly. In 1980, imports of high-tech manufactures supplied less than 4 percent of Japanese domestic consumption, rising to 5.6 percent in 1989, and then to 11 percent by 1995.

U.S. Trade Balance

The U.S. Bureau of the Census has developed a classification system for exports and imports of products that embody new or leading-edge technologies. This classification system allows trade to be examined in 10 major technology areas that have led to many leading-edge products. These 10 advanced technology areas are:

- **biotechnology**—the medical and industrial application of advanced genetic research toward the creation of new drugs, hormones, and other therapeutic items for both agricultural and human uses;
- **life science technologies**—application of scientific advances (other than biological) to medical science (for

Figure 6-10.
Import share of domestic high-tech markets



See appendix table 6-5.

Science & Engineering Indicators – 1998

example, medical technology advances such as nuclear resonance imaging, echocardiography, and novel chemistry, coupled with new production techniques for the manufacture of drugs, have led to new products that allow for the control or eradication of disease);

- ♦ **opto-electronics**—development of electronic products and components that involve emission or detection of light, including optical scanners, optical disk players, solar cells, photosensitive semiconductors, and laser printers;
- ♦ **computers and telecommunications**—development of products that process increasing volumes of information in shorter periods of time, including fax machines, telephone switching apparatus, radar apparatus, communications satellites, central processing units, computers, and peripheral units such as disk drives, control units, modems, and computer software;
- ♦ **electronics**—development of electronic components (except opto-electronic components), including integrated circuits, multilayer printed circuit boards, and surface-mounted components, such as capacitors and resistors, that result in improved performance and capacity and, in many cases, reduced size;
- ♦ **computer-integrated manufacturing**—development of products for industrial automation, including robots, numerically controlled machine tools, and automated guided vehicles that allow for greater flexibility in the manufacturing process and reduce the amount of human intervention;
- ♦ **material design**—development of materials, including semiconductor materials, optical fiber cable, and videodisks, that enhance application of other advanced technologies;
- ♦ **aerospace**—development of technologies, such as most new military and civil airplanes, helicopters, and spacecraft (with the exception of communications satellites), turbojet aircraft engines, flight simulators, and automatic pilots;
- ♦ **weapons**—development of technologies with military applications, including guided missiles, bombs, torpedoes, mines, missile and rocket launchers, and some firearms; and
- ♦ **nuclear technology**—development of nuclear production apparatus, including nuclear reactors and parts, isotopic separation equipment, and fuel cartridges (nuclear medical apparatus is included in life science rather than this category).

To be included in a category, a product must contain a significant amount of one of the leading-edge technologies, and the technology must account for a significant portion of the product's value.[5] Because the characteristics of products exported by the United States are likely to differ from the products it imports, experts evaluated exports and imports separately.

The Importance of Advanced Technology Product Trade to Overall U.S. Trade

U.S. trade in advanced technology products accounted for 17 to 20 percent of all U.S. trade (exports plus imports) in merchandise between 1990 and 1996. (See text table 6-3.) Total U.S. trade exceeded $1.4 trillion in 1996; $285 billion

[5]The advanced technology product system of trade data discussed here allows for a highly disaggregated, focused examination of technology embodied in traded goods. To minimize the impact of subjective classification, the judgments offered by government experts are subsequently reviewed by external experts.

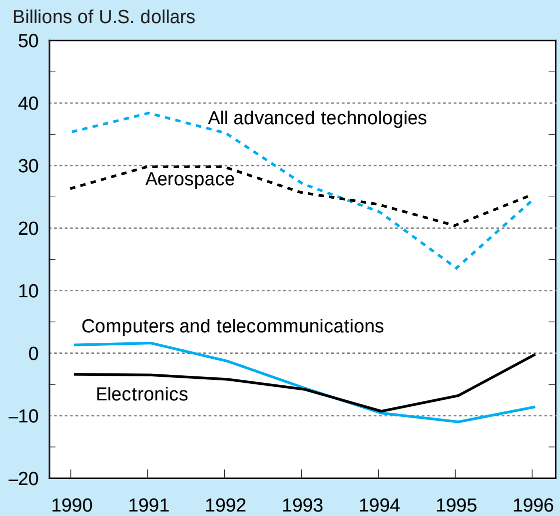
involved trade in advanced technology products. Trade in advanced technology products accounts for a much larger share of U.S. exports than of imports (25 percent versus nearly 16 percent in 1996) and makes a positive contribution to the overall balance of trade. After several years in which the surplus generated by trade in advanced technology products declined, preliminary data for 1996 show a larger surplus than in 1995. (See figure 6-11 and text table 6-3.)

Technologies Generating a Trade Surplus

Between 1990 and 1995, the U.S. trade surplus in software technology doubled, and trade in computer-integrated manufacturing technologies—those used to automate the manufacturing process—generated a sizable surplus. During this same period, trade in aerospace technologies consistently produced large, albeit declining, trade surpluses for the United States. Aerospace technologies generated a net inflow of $26 billion in 1990, and almost $30 billion in 1991 and 1992; the U.S. trade surplus in aerospace technologies then declined 14 percent in 1993, 9 percent in 1994, and 14 percent in 1995. While U.S. aerospace companies continue to lead the world in aircraft production and global shipments, Europe's aerospace industry now challenges U.S. companies' preeminence both at home and in foreign markets. The impact of Europe's Airbus is evident in the trade data. In 1990, U.S. trade in aerospace technologies with Germany, the United Kingdom, France, and Italy produced a $5.5 billion trade surplus. In 1995, the U.S. trade surplus with Europe was less than half that amount ($2 billion).

In 1990, opto-electronics and electronics products were the only advanced technology areas that produced net trade deficits for the United States. However, since 1992, the United States has had trade deficits in three areas: opto-electronics, electronics, and computers and telecommunications. Trade deficits with several Asian economies in these three advanced technology areas now exceed the trade surpluses generated from trade with other countries.

Figure 6-11.
U.S. trade balance in top three advanced technology products



See appendix table 6-6. *Science & Engineering Indicators – 1998*

U.S. Royalties and Fees Generated From Intellectual Property

The United States has traditionally maintained a large surplus in international trade of intellectual property. Firms trade intellectual property when they license or franchise proprietary technologies, trademarks, and entertainment products to entities in other countries. These transactions generate net revenues in the form of royalties and licensing fees.

U.S. Royalties and Fees From All Transactions

U.S. receipts from all trade in intellectual property reached $26.9 billion in 1995, a 21 percent increase over 1994. The

Text table 6-3.
U.S. international trade in merchandise
(Billions of U.S. dollars)

	1990	1991	1992	1993	1994	1995	1996
Total exports	393.0	421.9	447.5	464.8	512.4	575.9	611.5
Technology products (percent)	24.1	24.1	23.9	23.3	23.6	24.0	25.3
Other merchandise (percent)	75.9	75.9	76.1	76.7	76.4	75.0	74.7
Total imports	495.3	488.1	532.4	580.5	663.8	749.4	799.3
Technology products (percent)	11.0	12.0	13.5	13.0	14.8	16.7	16.3
Other merchandise (percent)	88.0	87.0	86.5	86.0	85.2	83.3	83.7
Total trade	888.3	910.0	979.9	1,045.3	1,176.2	1,325.3	1,410.8
Technology products (percent)	17.3	18.1	18.3	18.1	18.6	19.9	20.2
Other merchandise (percent)	82.7	81.9	81.7	81.9	81.4	80.1	79.8

NOTE: Total trade is the sum of total exports and total imports.

SOURCE: U.S. Bureau of the Census, Foreign Trade Division, <<http://www.fedstats.gov>>, 1997. *Science & Engineering Indicators – 1998*

1995 surplus continued a steady upward trend, which has resulted in a doubling of U.S. receipts in just six years. (See appendix table 6-7.) During the 1987-95 period, U.S. receipts were generally four to five times as large as U.S. payments to foreign firms for intellectual property. Most (about 75 percent) of the transactions involved exchanges of intellectual property between U.S. firms and their foreign affiliates.[6] (See figure 6-12.)

Exchanges of intellectual property among affiliates continue to grow faster than those among unaffiliated firms. This trend suggests a growing internationalization of U.S. business and a desire to retain a high level of control on any intellectual property leased overseas.

U.S. Royalties and Fees From Trade in Technical Knowledge

Data on royalties and fees generated by trade in intellectual property can be further disaggregated to reveal U.S. trade in technical know-how. These data describe transactions between unaffiliated firms where prices are set through a market-based negotiation. Therefore, they better reflect the exchange of technical know-how and its market value at a given point in time than do data on exchanges among affiliated firms. When receipts (sales of technical know-how) consistently exceed payments (purchases), these data may indicate a comparative advantage in the creation of industrial technology. The record of resulting receipts and payments also provides an indicator of the production and diffusion of technical knowledge.

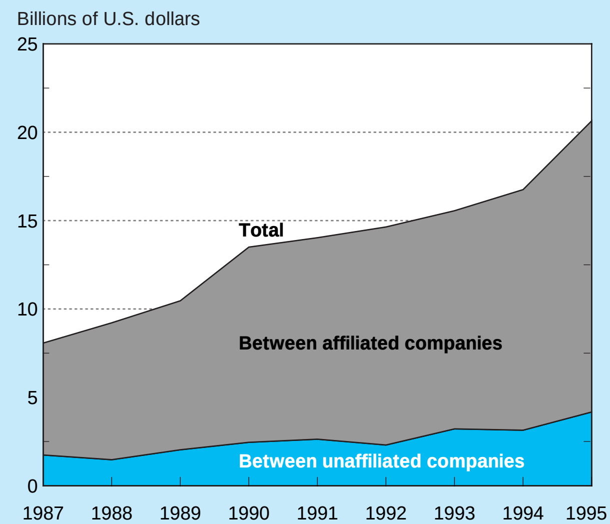
The United States is a net exporter of technology sold as intellectual property. Royalties and fees received from foreign firms have been, on average, three times those paid out by U.S. firms to foreigners for access to their technology. U.S. receipts from such technology sales exceeded $3.3 billion in 1995, up from $3.0 billion in 1994, and nearly double that reported for 1987. (See figure 6-13 and appendix table 6-8.)

Japan is the largest consumer of U.S. technology sold as intellectual property. In 1995, Japan accounted for over 45 percent of all such receipts, while the European Union (EU) countries together represented about 20 percent. Another Asian country, South Korea, is the second largest consumer of U.S. technology sold as intellectual property; it has maintained that position since 1988, when it accounted for 5.5 percent of U.S. receipts. South Korea's share rose to 10.7 percent in 1990, and to 17.6 percent in 1995.

To a large extent, the U.S. surplus in the exchange of intellectual property is driven by trade with Asia. In 1995, U.S. receipts (exports) from technology licensing transactions were eight times U.S. firm payments (imports) to Asia. As previously noted, Japan and South Korea were the biggest customers for U.S. technology sold as intellectual property—together, these countries accounted for over 50 percent of total receipts in 1995.

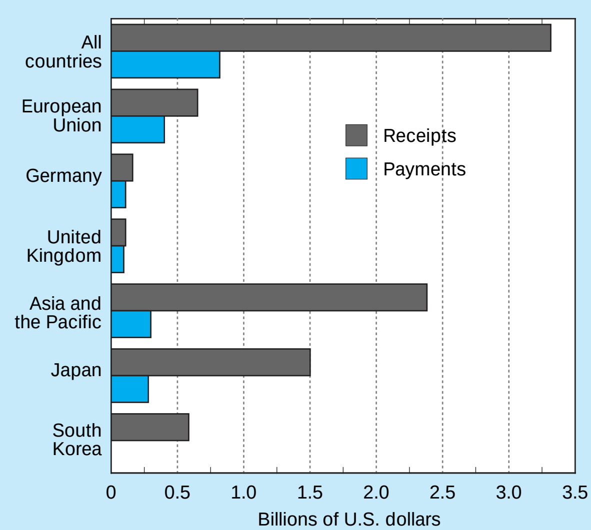
The U.S. experience with Europe has been very different from that with Asia. Over the years, U.S. trade with Europe in intellectual property has bounced back and forth, showing either a small surplus or deficit each year. In 1995,

Figure 6-12.
U.S. trade balance of royalties and fees



See appendix table 6-7. *Science & Engineering Indicators – 1998*

Figure 6-13.
U.S. royalties and fees generated from the exchange of industrial processes between unaffiliated companies: 1995



See appendix table 6-8. *Science & Engineering Indicators – 1998*

[6] An affiliate refers to a business enterprise located in one country that is directly or indirectly owned or controlled by an entity of another country to the extent of 10 percent or more of its voting stock for an incorporated business or an equivalent interest for an unincorporated business.

U.S.-Europe trade produced the largest surplus in the nine years examined, the result of a sharp decline in U.S. purchases of technical know-how from the smaller European countries.

Foreign sources for U.S. firm purchases of technical know-how have changed somewhat over the years, with increasing amounts coming from Japan. Europe still accounts for nearly 60 percent of the foreign technical know-how purchased by U.S. firms, with France, Germany, and the United Kingdom being the principal European suppliers. But, since 1990, Japan has been the single largest foreign supplier of technical know-how to U.S. firms.

International Trends in Industrial R&D

In high-wage countries like the United States, industries stay competitive in a global marketplace through innovation. Innovation can lead to better production processes and better performing products (i.e., those that are more durable, more energy efficient, etc.); it can thereby provide the competitive advantage high-wage countries require when competing with low-wage countries.

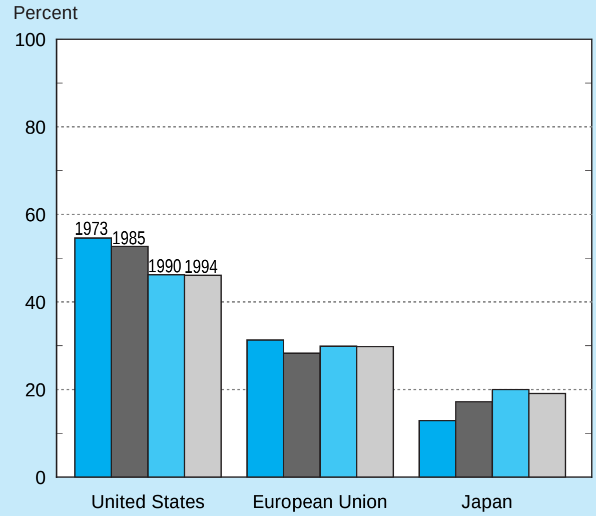
R&D activities serve as an incubator for the new ideas that can lead to new products, processes, and industries. While they are not the only source of new innovations, R&D activities conducted in industry-run laboratories and facilities are associated with many of the important new ideas that have helped shape modern technology.

U.S. industries that traditionally conduct large amounts of R&D have met with greater success in foreign markets than less R&D-intensive industries and have been more supportive of higher wages for their employees.[7] Moreover, trends in industrial R&D performance serve as leading indicators of future technological performance. This section examines these R&D trends, focusing particularly on growth in industrial R&D activity in the top R&D-performing industries of the United States and of its two major competitors in the global marketplace, Japan and the European Union.[8]

Overall Trends

The United States has long led the industrialized world in the performance of industrial R&D. Over the past two decades, however, the U.S. edge has diminished. Specifically, the U.S. share of total industrial R&D performed by all OECD member countries was 55 percent in 1973 and 46 percent in 1994.[9] (See figure 6-14.) Despite this decline, the United States remains the leading performer of industrial R&D by a wide margin, even surpassing the combined R&D of the 15-nation European Union. For its part, Japan—in keeping with its belief in the economic benefits of investments in R&D—rapidly increased R&D spending in the 1970s and 1980s, which led to a near doubling of its share of total OECD R&D by 1990. Preliminary data for 1995 indicate a 1 percentage point rise in the U.S. share, a 1 percentage point decline for Japan, and no change for the European Union.

Figure 6-14.
Percent shares of total industrial R&D in OECD countries



SOURCE: Organisation for Economic Co-operation and Development, Analytical Business Enterprise R&D Database (Paris: 1997).

Science & Engineering Indicators – 1998

R&D Performance by Industry

The United States, the European Union, and Japan represent the three largest economies in the industrialized world and compete head to head in the international marketplace. An analysis of R&D data provides some explanation for past successes in certain product markets, provides insights into future product development, and signals shifts in national technology priorities.[10]

United States

R&D performance by U.S. industry followed a pattern of rapid growth during the 1970s, which accelerated during the early 1980s. That growth pattern stalled during the latter part of the decade and into the 1990s. When adjusted for inflation, growth in U.S. industrial R&D performance over the last decade has steadily dropped from only meager growth

[7]See “U.S. Technology in the Marketplace” for a presentation of recent trends in U.S. competitiveness in foreign and domestic product markets.

[8]This section uses data from OECD’s Analytical Business Enterprise R&D Database (OECD 1997) to examine trends in national industrial R&D performance. This database tracks all R&D expenditures (both defense- and nondefense-related) carried out in the industrial sector, regardless of funding source. For an examination of U.S. industrial R&D by funding source, see chapter 4.

[9]OECD member countries include Australia, Austria, Belgium, Canada, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Luxembourg, Mexico, the Netherlands, New Zealand, Norway, Poland, Portugal, South Korea, Spain, Sweden, Switzerland, Turkey, the United Kingdom, and the United States.

[10]Industry-level data are occasionally estimated here in order to provide a complete time series for the 1973-94 period.

to actual decline in 1993 and 1994 (by 2.7 and 0.2 percent, respectively, in 1987 constant dollars).

The downturn in growth would be far more dramatic were it not for the growth in R&D performed by U.S. service sector industries. While the growth in R&D performance by U.S. manufacturers has slowed since the mid-1980s, R&D performance by U.S. service sector industries has grown rapidly. (See figure 6-15.) The latest internationally comparable data on overall U.S. industrial R&D performance show the service sector's share rising from 4 percent in 1982 to 24 percent by 1992. The specific industries driving this increase in R&D performance within the U.S. service sector include those developing computer software and providing communication services.

Overall, the U.S. aerospace and communications equipment industries have consistently been the largest performers of R&D in this country. Comparing performance in 1984 and 1994, however, shows a shift in the nation's R&D emphasis. More R&D is being performed in the automotive industry, in the industry producing scientific instruments, and in the service sector industries. Service sector industries as a group accounted for a larger share of U.S. industrial R&D performance than either the aerospace industry or the automobile industry—the top two R&D-performing industries in the U.S. manufacturing sector in 1994.

Japan

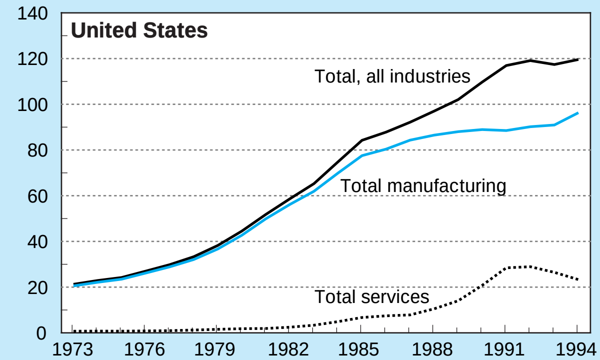
During the 1970s, R&D performance in Japanese industries grew at a higher rate than in the United States. Japanese industry continued to expand its R&D spending rapidly through 1985, more than doubling the annualized growth of the previous decade. Japanese industrial R&D spending slowed somewhat during the second half of the 1980s, but the country still led all other industrialized nations in terms of average annual growth in industrial R&D. Unlike the declining trend observed for manufacturing industries in the United States, Japanese manufacturing industries consistently accounted for over 95 percent of all R&D performed by Japanese industry. R&D in Japanese service sector industries appears to have accelerated during the 1990s, but the country's industrial R&D continues to be dominated by the manufacturing sector. (See figure 6-15.)

An examination of growth trends for the top five R&D-performing industries in Japan reflects that country's long-standing emphasis on electronics (including consumer electronics and all types of audiovisual equipment). This industry was the leading performer of R&D throughout the period reviewed. Japan's motor vehicle industry was the third leading R&D performer in 1973, but rose to number two in 1980 and remained at that level through 1992. Japanese automakers earned a reputation for high quality and value during these years, which earned them increasingly larger shares of the global car market.

Electrical machinery producers are also among the largest R&D performers in Japan and have maintained high R&D growth throughout the period examined. By 1994, in fact,

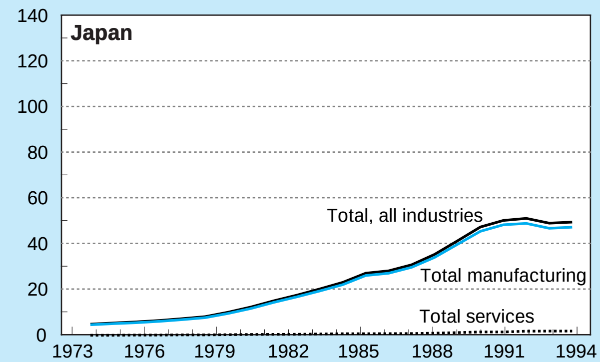
Figure 6-15.
Industrial R&D performance

Billions of current purchasing power parity dollars



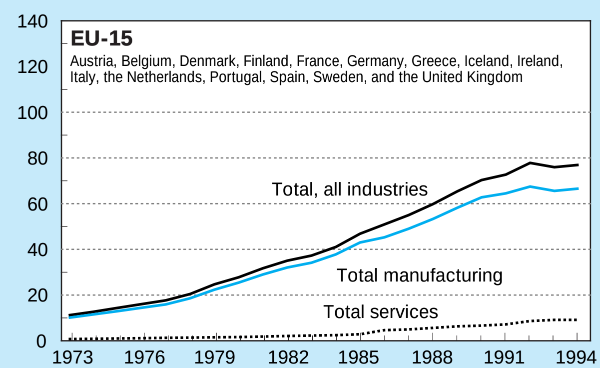
Top industrial R&D performers and their share of total industrial R&D

1974		1984		1994	
Aerospace	23.1%	Aerospace	25.2%	Services (total)	19.5%
Electrical equipment & components	13.0%	Electrical equipment & components	15.9%	Aerospace	11.9%
Motor vehicles	10.4%	Office machinery & computers	10.8%	Motor vehicles	11.2%
Office machinery & computers	9.2%	Motor vehicles	8.1%	Electrical equipment & components	10.6%
Electrical machinery	8.9%	Services (total)	6.6%	Instruments	9.6%



Top industrial R&D performers and their share of total industrial R&D

1974		1984		1994	
Electrical equipment & components	15.6%	Electrical equipment & components	17.9%	Electrical equipment & components	16.5%
Industrial chemicals	14.2%	Motor vehicles	13.0%	Electrical machinery	11.2%
Non-electrical machinery	11.6%	Industrial chemicals	10.9%	Motor vehicles	11.1%
Motor vehicles	11.3%	Electrical machinery	10.5%	Industrial chemicals	10.2%
Electrical machinery	10.0%	Non-electrical machinery	8.6%	Non-electrical machinery	9.3%



Top industrial R&D performers and their share of total industrial R&D

1974		1984		1994	
Electrical equipment & components	15.1%	Electrical equipment & components	18.5%	Electrical equipment & components	15.4%
Industrial chemicals	13.9%	Industrial chemicals	12.4%	Motor vehicles	13.4%
Aerospace	13.2%	Motor vehicles	11.2%	Services (total)	11.7%
Motor vehicles	9.9%	Aerospace	10.7%	Industrial chemicals	10.4%
Electrical machinery	8.4%	Electrical machinery	7.4%	Pharmaceuticals	10.0%

See appendix tables 6-9, 6-10, and 6-11.

Science & Engineering Indicators – 1998

this industry had moved up to become Japan's second leading R&D-performing industry. In comparison, the U.S. electrical machinery industry's ranking among the top R&D performers in the United States has dropped since 1973.

European Union

Like Japan and the United States, manufacturing industries perform the bulk of industrial R&D in the 15-nation European Union. The European Union's industrial R&D appears to be somewhat less concentrated than in the United States, but more so than in Japan. Manufacturers of electronics equipment, industrial chemicals, and motor vehicles have consistently been among the top five performers of industrial R&D in the European Union. (See figure 6-15.) In 1994, Germany led the European Union in the performance of motor vehicle and industrial chemical R&D, while France led in industrial R&D performed by communications equipment manufacturers.

R&D performed by the European Union's service sector has doubled since the mid-1980s, accounting for nearly 12 percent of total industrial R&D performed by 1994. Large increases in service sector R&D are apparent in many EU countries, but especially in the United Kingdom (23.6 percent of its industrial R&D in 1994), Italy (13.8 percent), and France (9.5 percent).

Patented Inventions

New technical inventions have important economic benefits to a nation, as they can often lead to innovations in terms of new or improved products or more efficient manufacturing processes—or even to new industries. To foster inventive activity, nations assign property rights to inventors in the form of patents, which allow the inventor to exclude others from making, using, or selling the invention. Inventors can obtain patents from government-authorized agencies for inventions judged to be new, useful, and non-obvious.

Patent data provide useful indicators of technical change and serve as a means of measuring inventive output over time.[11] Further, U.S. patenting by foreign inventors enables measurement of the levels of invention in those foreign countries (Pavitt 1985) and can serve as a leading indicator of new technological competition (Faust 1984). Patenting trends can therefore serve as an indicator—albeit one with certain limitations—of national inventive activities.[12]

This section describes broad trends in inventive activity in the United States over time by national origin of owner, patent office class, patent activity, and commerce activity. It discusses U.S. inventor patenting in foreign countries and presents data on international patenting in several "critical" technologies.

U.S. Patenting

In 1994, for the first time ever, more than 100,000 patents were issued in the United States. This record number—101,675—of new inventions resulting in new patents caps off what had been several years of steady increases since 1990. In 1995, U.S. patents granted fell short of the previous year's mark, but not by much. Once again, more than 100,000 patents were granted, with the final count reaching 101,419 in 1995.

Patents Granted to U.S. Inventors

During the mid-1980s, the number of U.S. patents awarded to U.S. inventors began to decline just as the number awarded to foreign inventors began to rise. This of course raised questions about U.S. inventive activity and whether these numbers were yet another indicator of U.S. competitiveness on the decline. By the end of the decade, however, U.S. inventor patenting picked up and continued to increase and outpace foreign inventor patenting in the United States. In 1989, there was a large jump in the number of new patents awarded to U.S. inventors; that year also marked the first time the number of patents awarded to U.S. inventors exceeded 50,000. Except for the following year (1990), the 50,000 barrier was exceeded each year thereafter. In 1995, U.S. inventors received 55,739 patents. (See figure 6-16 and appendix table 6-12.)

Inventors who work for private companies or the Federal Government commonly assign ownership of their patents to their employers; self-employed inventors typically retain ownership of their patents. Examining patent data by owner's sector of employment can therefore provide a good indication of the sector in which the inventive work was done. In 1995, 79 percent of granted U.S.-origin patents were owned by U.S. corporations.[13] (See "Top Patenting Corporations.") This percentage has increased gradually over the years.[14]

---

[11]See Griliches (1990) for a survey of literature related to this point.

[12]Although the U.S. Patent and Trademark Office grants several types of patents, this discussion is limited to utility patents only, which are commonly known as "patents for inventions." Patenting indicators have several well-known drawbacks, including the following:

- **incompleteness—**many inventions are not patented at all, in part because laws in some countries already provide for the protection of industrial trade secrets;
- **inconsistency across industries and fields—**industries and fields vary considerably in their propensity to patent inventions, and consequently, it is not advisable to compare patenting rates among different industries or fields (Scherer 1992); and
- **inconsistency in quality—**the importance of patented inventions can vary considerably (although patent citation rates, discussed later in this section as well as in chapter 5, are one method for dealing with this question of varying quality).

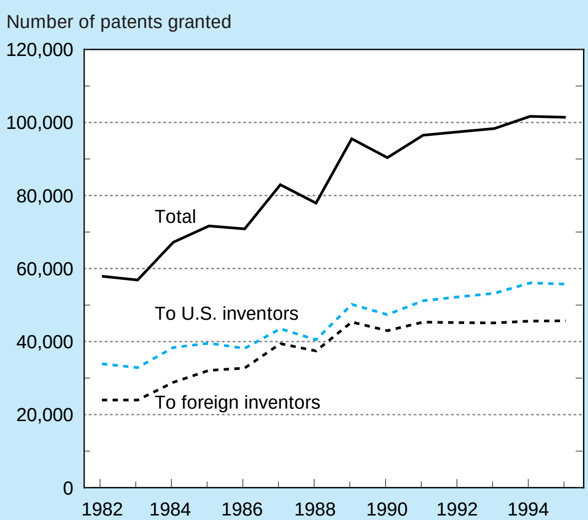
Despite these and other limitations, patents provide a unique source of information on inventive activities.

[13]About 3.3 percent of patents granted to U.S. inventors in 1995 were owned by U.S. universities and colleges. The U.S. Patent and Trademark Office counts these as being owned by corporations. For further discussion of academic patenting, see chapter 5, "Patents Awarded to U.S. Universities."

[14]Over the past 15 years, corporate-owned patents accounted for between 74 and 79 percent of total U.S.-owned patents.

After business entities, individuals are the next largest group of U.S.-origin patent owners. Prior to 1982, individuals owned, on average, 24 percent of all patents granted.[15] Their share has fluctuated between 23 and 27 percent since then. In 1995, the 23 percent share accounted for by individuals matched similar period lows in 1994. The federal share of patents averaged 3.4 percent of the total during the period 1963-82; thereafter, U.S. Government-owned patents as a share of total U.S.-origin patents declined.[16] U.S. Government-owned patents were encouraged by legislation enacted during the 1980s, which called for U.S. agencies to establish new programs and increase incentives to their scientists, engineers, and technicians that would facilitate the transfer of technology developed in the course of government activities.[17] (See "Private Use of Public Science.")

Figure 6-16.
U.S. patents granted, by nationality of inventor



See appendix table 6-12. *Science & Engineering Indicators – 1998*

Top Patenting Corporations

An examination of the top patenting corporations in the United States over the past 23 years underscores the rapid technological transformation achieved by Japan over a relatively short period. In 1973, there were no Japanese companies among the top 10 patenting corporations in the United States. In 1983, there were three Japanese companies among the top 10. By 1993, Japanese companies outnumbered U.S. companies, and the most recent data show eight Japanese companies among the top 10. (See text table 6-4.) Japan's patenting now emphasizes computer technologies, television and communications technologies, and power generation technologies.

Text table 6-4.
Top patenting corporations

Company	Number of patents
In 1996	
International Business Machines Corp.	1,867
Canon Kabushiki Kaisha	1,541
Motorola Inc.	1,064
NEC	1,043
Hitachi, LTD	963
Mitsubishi Denki Kabushiki Kaisha	934
Toshiba Corporation	914
Fujitsu Limited	869
Sony Corporation	855
Matsushita Electric Industrial Co., Ltd.	841
From 1977-96	
General Electric Corp.	16,206
International Business Machines Corp.	15,205
Hitachi, LTD	14,500
Canon Kabushiki Kaisha	13,797
Toshiba Corporation	13,413
Mitsubishi Denki Kabushiki Kaisha	10,192
U.S. Philips Corporation	9,943
Eastman Kodak Company	9,729
AT&T Corporation	9,380
Motorola Inc.	9,143

SOURCE: U.S. Patent and Trademark Office, Office of Information Systems, TAF Program. *Science & Engineering Indicators – 1998*

Patents Granted to Foreign Inventors

Foreign-origin patents represent nearly half (45 percent in 1995) of all patents granted in the United States.[18] Their share rose throughout most of the 1980s before edging downward in 1989. At their peak in 1988, foreign-origin patents accounted for 48 percent of total U.S. patents. Since then, with U.S. inventor patenting increasing faster than foreign inventor patenting, the foreign inventor share has declined several percentage points. (See appendix table 6-12.)

[15]Prior to 1982, data are provided as a total for the period 1963-82.

[16]Federal inventors frequently obtain a statutory invention registration (SIR) rather than a patent. An SIR is not ordinarily subject to examination, and it costs less to obtain than a patent. Also, an SIR gives the holder the right to use the invention but does not prevent others from selling or using it as well.

[17]The Stevenson-Wydler Technology Innovation Act of 1980 made the transfer of federally owned or originated technology to state and local governments and to the private sector a national policy and the duty of government laboratories. The act was amended by the Federal Technology Transfer Act of 1986 to provide additional incentives for the transfer and commercialization of federally developed technologies. Later, Executive Order 12591 of April 1987 ordered executive departments and agencies to encourage and facilitate collaborations among federal laboratories, state and local governments, universities, and the private sector—particularly small business—in order to aid technology transfer to the marketplace. In 1996, Congress strengthened private sector rights to intellectual property resulting from these partnerships.

[18]Corporations account for about 80 percent of all foreign-owned U.S. patents.

Private Use of Public Science

Industry makes good use of public science, according to an analysis of more than 100,000 patent-to-science references conducted by CHI Research, Inc. (see Narin, Hamilton, and Olivastro 1997.) This study showed that 73 percent of the references to scientific publications listed as "prior art" on the front pages of U.S. patents were to public science—i.e., authored at academic, governmental, and other public institutions. (See text table 6-5.) The public science cited in these references was at the *basic* end of the research spectrum and was "…published in influential journals, authored at top-flight research universities and laboratories, was relatively recent, and heavily supported by NIH [the National Institutes of Health], NSF [the National Science Foundation], and other public agencies" (Narin, Hamilton, and Olivastro 1997). The institutions performing publicly funded research typically produce 90 percent of the articles that appear in the main influential scientific and technical journals. Nevertheless, that so much of it so quickly contributes to private sector technological breakthroughs is an important indicator of the potential economic impact of publicly funded research.

The analysis also found that the number of references to public science had nearly tripled over a recent six-year period (from 1987-88 to 1993-94), suggesting that the linkage between patented technologies and contemporary public science is growing. The availability of better electronic search tools to inventors and patent examiners in the more recent period might help to explain this trend, but researchers do not credit it alone with the tripling of science citations on U.S. patents.

The study concludes that there are strong linkages between contemporary public science and technological breakthroughs patented in the United States, and that these linkages are becoming stronger. These findings are consistent with other indicators of increased linkages and collaborations of industry with academia and national labs. (See chapters 4 and 5.)

Text table 6-5.
Number of citations from 1993-94 U.S. patents to top 15 author institutions

Biomedical papers		Chemistry papers		Physics papers		Engineering & technology papers	
Harvard University	2,506	MIT	171	Bell Labs	854	Bell Labs	471
National Cancer Institute	1,279	University of Texas at Austin	171	IBM Corp.	566	IBM Corp.	428
Veterans Administration	1,033	Harvard University	160	Stanford University	300	University of California–Berkeley	189
University of California–San Francisco	930	DuPont Co.	142	Bellcore	174	MIT	179
Stanford University	920	University of California–Berkeley	139	U.S. Naval Research Lab	167	Stanford University	162
University of Washington	845	Bell Labs	130	Lincoln Labs	150	General Electric Co.	111
MIT	756	IBM Corp.	122	MIT	133	Texas Instruments Inc.	96
Scripps Clinic & Research Foundation	690	Merck & Co. Inc.	102	University of Illinois	120	U.S. Naval Research Lab	88
University of California–Los Angeles	642	Cornell University	96	University of California–Santa Barbara	110	North Carolina State University	84
Massachusetts General Hospital	625	Texas A&M University	95	Cornell University	106	Bellcore	78
Johns Hopkins University	610	Pennsylvania State University	89	University of California–Berkeley	100	Xerox Corp.	69
Washington University	588	University of Wisconsin	87	Xerox Corp.	95	University of Illinois	64
University of California–San Diego	534	Purdue University	83	University of Pennsylvania	93	Pennsylvania State University	60
University of Pennsylvania	517	University of Illinois	83	North Carolina State University	90	University of California–Los Angeles	59
Merck & Co., Inc.	484	University of California–Los Angeles	79	Caltech	87	Lincoln Labs	57

SOURCE: Narin, Hamilton, and Olivastro 1997

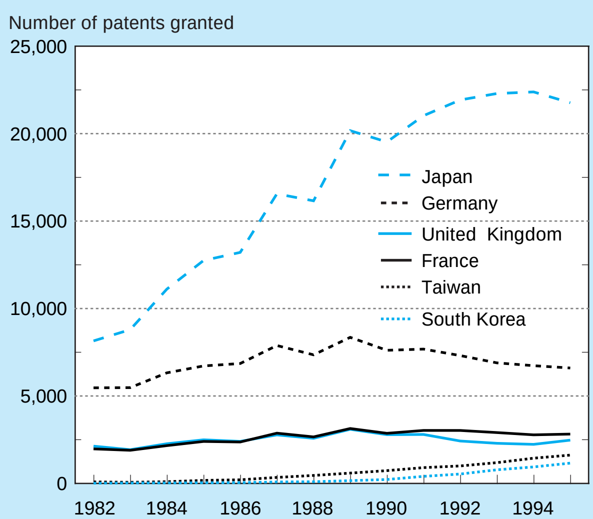
Science & Engineering Indicators – 1998

Foreign patenting in the United States is highly concentrated by country of origin. In 1995, two countries—Japan and Germany—accounted for over 60 percent of U.S. patents granted to foreign inventors. The top five countries—Japan, Germany, France, the United Kingdom, and Canada—accounted for 80 percent. (See figure 6-17.) These data show a slowdown in U.S. patenting activity by inventors from these five countries. From 1982 to 1992, U.S. patenting activity by inventors from these five countries nearly doubled, peaking in 1992 at nearly 37,000 U.S. patents. Patenting by Japanese and French inventors was especially strong during this period.

Since then, patenting by inventors from the leading industrialized countries has leveled off and has even begun to decline in some instances.[19] France, Germany, and Japan were each awarded fewer U.S. patents in 1995 than in 1992. The United Kingdom and Canada increased their patenting, but only slightly. Other countries, particularly Asian countries outside Japan, have stepped up their patenting activity in the United States and are showing themselves to be strong inventors of new technologies. This is especially true for Taiwan and South Korea. Before 1982 (data are available starting in 1963), Taiwan was awarded just 316 U.S. patents. Between 1982 and 1995, Taiwan was awarded nearly 9,000 U.S. patents. U.S. patenting activity by inventors from South Korea shows a similar growth pattern. Before 1982, South Korea was awarded just 102 U.S. patents; since then, more than 4,500 new patents have been awarded. Inventors from China and Hong Kong also rapidly increased their patenting in the United States since 1982. Even so, when the number of U.S. patents awarded to China and Hong Kong in 1995 are combined, they represent less than one-tenth the number awarded to Taiwan in that year.

[19]Some of the decline in U.S. patenting by inventors from the leading industrialized nations may be attributed to the move toward European unification, which has encouraged wider patenting within Europe.

Figure 6-17.
U.S. patents granted to foreign inventors, by nationality of inventor



See appendix table 6-12. *Science & Engineering Indicators – 1998*

Technical Fields Favored by Foreign Inventors

A country's distribution of patents by technical area has proved to be a reliable indicator of a nation's technological strengths, as well as an indicator of direction in product development. This section compares and discusses the various key technical fields favored by inventors in the world's three leading economies—the United States, Japan, and Germany—and in two newly industrialized economies—Taiwan and South Korea.[20]

Fields Favored by U.S., Japanese, and German Inventors

While U.S. patent activity spans a wide spectrum of technology and new product areas, U.S. corporations' patenting shows a particular emphasis on several of the technology areas that are expected to play an important role in future economic growth (U.S. OSTP 1997). In 1995, corporate patent activity reflected U.S. technological strengths in developing new medical and surgical devices, electronics, telecommunications, advanced materials, and biotechnology. (See text table 6-6 and appendix table 6-13.)

The 1995 patent data continue to show Japanese inventors emphasizing technology classes associated with photography, photocopying, and consumer electronics industries. (See appendix table 6-14.) What is also evident in 1995 is the broader range of U.S. patents awarded to Japanese inventors in information technology. From improved information storage technology for computers to visual display systems, Japanese inventions are earning U.S. patents in areas that aid the processing, storage, and transmission of information.

German inventors continue to develop new products and processes in technology areas associated with heavy manufacturing industries in which that country has traditionally maintained a strong presence. The 1995 U.S. patent activity index shows a German emphasis on motor vehicles, printing, new chemistry and advanced materials, and material handling equipment patent classes. (See appendix table 6-15.) German inventors have also stepped up their patent activity in some newer technology areas, such as biotechnology and opto-electronics.

[20]Information in this section is based on the U.S. Patent and Trademark Office's classification system, which divides patents into approximately 370 active classes. With this system, patent activity for U.S. and foreign inventors in recent years can be compared by developing an activity index. For any year, the activity index is the proportion of patents in a particular class granted to inventors in a specific country divided by the proportion of all patents granted to inventors in that country. Because U.S. patenting data reflect a much larger share of patenting by individuals without corporate or government affiliation than do data on foreign patenting, only patents granted to corporations are used to construct the U.S. patenting activity indices.

Fields Favored by Two Newly Industrialized Economies

Patent activity in the United States by inventors from newly industrialized economies can be seen as an indicator of these economies' technological development and as a leading indicator of U.S. product markets likely to see increased competition.

As recently as 1980, *Taiwan's* U.S. patent activity was primarily in the area of toys and other amusement devices. By the 1990s, Taiwan was active in such areas as communications technology, semiconductor manufacturing processes, and internal combustion engines (see NSB 1991). The latest available data (1995) show that inventors from Taiwan have continued to patent heavily in communications technologies and processes used in the manufacture of semiconductor devices; data also show heavy activity in computer storage and display devices, advanced materials, and transistors. (See text table 6-7 and appendix table 6-16.) Ten years earlier, inventors from Taiwan received no patents in any of these technology classes.

U.S. patenting by *South Korean* inventors has also shown rapid technological development. The 1995 data show that Korean inventors are patenting heavily in television technologies, electrical products, and advanced materials. (See text table 6-7 and appendix table 6-17.) South Korea's patenting has also expanded into a broader array of computer technologies that include devices for dynamic and static information storage, data generation and conversion, error detection, and display systems.

Both South Korea and Taiwan are already major suppliers of computers and peripherals to the United States. The recent patenting data show that their scientists and engineers are continuing to develop new technologies and improve existing technologies. It is likely that these new inventions will enhance these economies' competitiveness in the United States and in global markets.

Patenting Outside the United States

In most parts of the world, foreign inventors account for a much larger share of total patent activity than in the United States. When foreign patent activity in the United States is compared with that in 15 other important countries in 1985, 1990, and 1995, only Russia and Japan had less foreign patent activity. (See figure 6-18 and appendix table 6-18.)

What is often obscured by the rising trends in foreign-origin patents in the United States is the success and widespread activity of U.S. inventors in patenting their inventions around the world. U.S. inventors lead all other foreign

Text table 6-6.
Top 15 most emphasized U.S. patent classes for inventors from the United States, Japan, and Germany: 1995

	United States	Japan	Germany
1.	Wells	Dynamic information storage or retrieval	Fluid-pressure brake systems
2.	Surgery (class 606)	Photography	Printing
3.	Surgery (class 604)	Music	Brakes
4.	Surgery: light, thermal, and electrical applications	Photocopying	Conveyors: power driven
5.	Chemistry of hydrocarbons	Facsimile or television recording	Organic compounds (class 548)
6.	Special receptacle or package	Typewriting machines	Metal deforming
7.	Surgery (class 128)	Static information storage and retrieval	Organic compounds (class 546)
8.	Receptacles	Dynamic magnetic information storage or retrieval	Internal-combustion engines
9.	Supports	Active solid state devices	Sheet feeding or delivering
10.	Cryptography	Radiation imagery chemistry: process, composition	X-ray or Gamma ray devices
11.	Static structures (e.g., buildings)	Incremental printing	Plastic or earthenware shaping apparatus
12.	Processes, compositions for food or edible material	Optics: systems and element	Organic compounds (class 568)
13.	Amusement devices: games	Electrical generator	Organic compounds (class 549)
14.	Cleaning and liquid contact with solids	Television	Machine element or mechanism
15.	Chemistry: analytical and immunological testing	Metal treatment	Synthetic resins or natural rubbers (class 528)

See appendix tables 6-13, 6-14, and 6-15.

Science & Engineering Indicators – 1998

Text table 6-7.
Top 15 most emphasized U.S. patent classes for inventors from South Korea and Taiwan: 1995

	South Korea	Taiwan
1.	Electric lamp and discharge devices	Semiconductor device manufacturing process
2.	Semiconductor device manufacturing process	Selective visual display systems
3.	Television	Machine element
4.	Facsimile or television recording	Chairs and seats
5.	Dynamic information storage and retrieval	Electric lamp and discharge devices
6.	Dynamic magnetic information storage or retrieval	Active solid state devices (e.g., transistors)
7.	Static information storage and retrieval	Electrical nonlinear devices
8.	Winding, tensioning, or guiding	Illumination
9.	Electric heating	Plastic or earthenware shaping devices
10.	Error detection/correction	Supports
11.	Electric lamp and discharge devices, systems	Electricity, circuit makers and breakers
12.	Electricity: motive power systems	Wave transmission lines and networks
13.	Electrical audio signal processing systems	Land vehicles
14.	Active solid state devices (e.g., transistors)	Music
15.	Coded data generation or conversion	Static information storage and retrieval

See appendix tables 6-16 and 6-17.

Science & Engineering Indicators – 1998

inventors not just in countries neighboring the United States (Canada and Mexico), but also in distant markets such as Japan, Brazil, Hong Kong, India, Malaysia, and Thailand. (See figure 6-19.) Japanese inventors edge out Americans in Germany and the United Kingdom, and dominate foreign patenting in South Korea. German inventors lead all foreign inventors in France, Italy, and Russia; they are also quite active in many of the other countries examined.

International Patenting Trends for Three Important Technologies

This section explores the relative strength of America's technological position by examining international patenting patterns in three important technology areas: advanced manufacturing, biotechnology, and advanced materials.[21] To facilitate the patent search and analysis, these broad technology areas were each represented by a narrower subfield: robot technology as a proxy for advanced manufacturing, genetic engineering for biotechnology, and advanced ceramics for advanced materials.[22] To ensure maximum comparability of data, this analysis is built around the concept of a "patent family"—i.e., all the patent documents published in different countries associated with a single invention. (See "International Patent Families as a Basis for Comparison.")

International Patent Families as a Basis for Comparison

A patent family consists of all the patent documents associated with a single invention that are published in different countries. The first application filed anywhere in the world is the priority application: it is assumed that the country in which the priority application was filed is the country in which the invention was developed. Similarly, the priority year is the year the priority application was filed. The basic patent is the first patent or patent application published in any of the roughly 40 countries covered in the database used in this section. This database, the Derwent World Patents Index Latest, covers basic patents published from 1981 to the present.

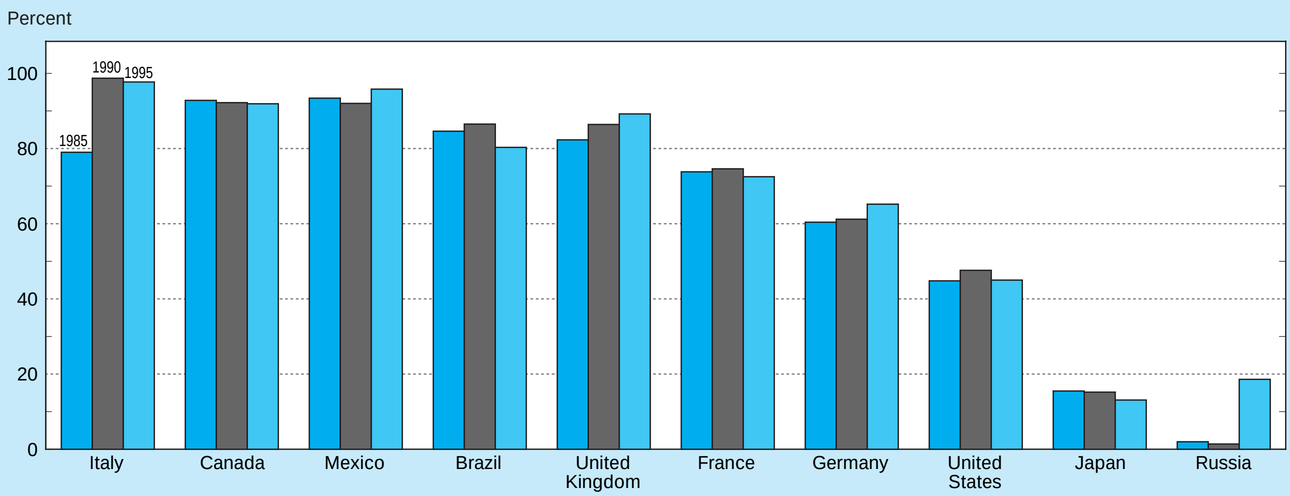
National patent systems, such as Japan's, that encourage large numbers of domestic patent applications skew counts of patent families over time as an indicator of technological activity. To eliminate this bias, international patent families are used as a basis of comparison. An international patent family is created when patent protection is sought in at least one other country besides that in which the earliest priority application was filed.

[21]Data in this section are drawn from a database containing patent records from about 40 major patenting countries, which facilitates a more comprehensive assessment of U.S. technological position vis-à-vis other national competitors. These data were developed under contract for the National Science Foundation by Mogee Research & Analysis Associates; they were extracted from the Derwent World Patents Index database published by Derwent Publications Ltd. The technology areas selected for this study met several criteria:

- Each technology appeared on the lists of "critical" technologies considered/deemed important to future U.S. economic competitiveness or national security (see Mogee 1991 and U.S. OSTP 1995).
- Each technology is characterized by the output of patentable products or processes.
- Each technology could be defined sufficiently to permit construction of accurate patent search strategies.
- Each technology yielded a sufficient population for statistical analysis.

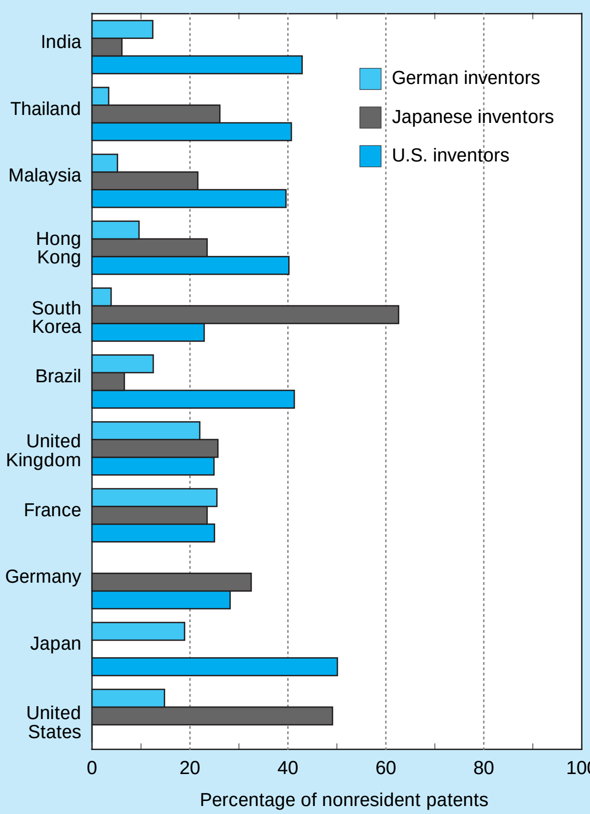
[22]These subfields were identified based on a review of recent critical technologies reports and extensive consultation with National Science Foundation staff and experts in the technologies to determine representative subfields.

Figure 6-18.
Share of total patents awarded to nonresident inventors



See appendix tables 6-12 and 6-18. *Science & Engineering Indicators – 1998*

Figure 6-19.
Patents granted to nonresident inventors: 1994



See appendix table 6-18. *Science & Engineering Indicators – 1998*

Three indicators are used here to compare national positions in each critical technology:

♦ **Trends in international inventive activity—**This indicator provides a first measure of the extent and growth of each nation's inventive activity considered important enough to be patented outside of the country of origin. These data are tabulated by priority year.

♦ **Highly cited inventions—**Interpatent citations are an accepted method of gauging the technological value or significance of different patents.[23] These citations, provided by the patent examiner, indicate the "prior art"—i.e., the technology in related fields of invention—that was taken into account in judging the novelty of the present invention.[24] The number of citations a patent receives from later patents can serve as an indicator of its technical importance or value. The technological significance indicator used here attempts to assess a country's contribution toward advancing the particular technology field

[23]Carpenter, Narin, and Woolf (1981) show that technologically important U.S. patents on average receive twice as many examiner citations as does the average U.S. patent, thus helping to confirm the validity of interpatent citation as an indicator of patent quality.

[24]The citations counted are those placed on European Patent Office (EPO) patents by EPO examiners. EPO citations are believed to be a less biased and broader source of citations than those of the U.S. Patent and Trademark Office. See Claus and Higham (1982).

by determining the number of highly cited international patent families from each priority country.[25]

- **International patent family size—**Given the significant costs associated with obtaining patent protection in multiple countries, it can be assumed that the number of countries in which protection has been sought may be indicative of an invention's commercial potential. An indicator attempting to measure the commercial potential of a nation's patented inventions is calculated in two steps: first, by computing mean family size for international patent families by priority country, and then by adjusting the mean family size for the size of the national markets in which protection is being sought.[26]

In each technology area, U.S. inventive activity is examined for the 1990-94 period, alongside that of five other countries: Japan, Germany, France, the United Kingdom, and South Korea.

Robot Technology

As used here, robot technology covers program-controlled manipulators—e.g., the manipulator, program control, gripping heads, joints, arm sensors, safety devices, and accessories—and excludes non-program-controlled manipulators, prosthetic devices, and toy robots.

International Patenting Activity. During the first half of the 1990s, 1,719 international patent families were formed in robotics, with priority applications in the six countries examined. (See figure 6-20.) Patenting activity in the six-country group accounts for about three-quarters of all families in this technology area.

The conventional perception of Japan as an innovator in the area of advanced manufacturing techniques is reinforced by the large number of robot inventions originating in Japan. Japan led all other countries studied in the total number of international patent families in robot technology created during the 1990-94 period. Japanese inventors held 43 percent of the total number of international patent families formed by the six countries included in the study, followed by the United States (24 percent), Germany (16 percent), France (9 percent), the United Kingdom (4 percent), and South Korea (3 percent).

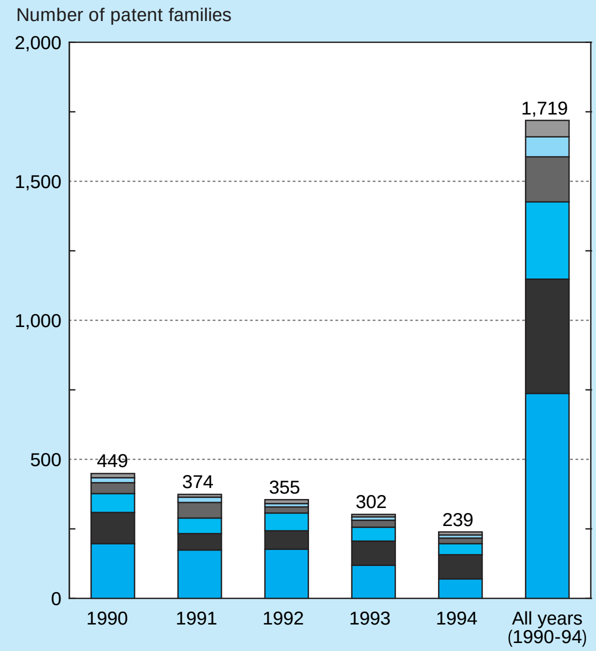
Japan ranks number one in patent activity when the entire five-year period is considered; however, this activity declined rapidly after 1992. At about the same time, U.S. activity picked up; in 1994, the United States led Japan in the number of international robot technology patent families formed.

Although South Korea's share of international patent families was the lowest overall, its share was comparable in size to that of the larger and more advanced economy of the United Kingdom (3.4 percent for Korea versus 4.2 percent for the United Kingdom). Given its newly industrialized economy status, South Korea's overall international inventive activity in this technology area is impressive—especially when the data show that South Korea's patenting activity in this technology area equaled that of the United Kingdom in 1994.

Highly Cited Robot Inventions.[27] On this indicator, the United States led all countries—and by a wide margin—with 55.6 percent of all highly cited robot technology international families generated during the 1990-94 period (10 of 18). Japan (with 33.3 percent of the highly cited patents) and Germany (with 11.1 percent) trailed distantly. (See text table 6-8.) The United Kingdom, France, and South Korea did not have any international robot families in the highly cited group.

[27]This indicator included all families with priority application dates from 1990 to 1994 with eight or more citations.

Figure 6-20.
Robot technology: Number of international patent families, by priority year and country



	1990	1991	1992	1993	1994	All years (1990-94)
South Korea	15	10	14	9	11	59
United Kingdom	18	19	12	12	11	72
France	39	56	22	25	20	162
Germany	68	56	64	50	40	278
United States	112	59	66	87	87	411
Japan	197	174	177	119	70	737

SOURCE: Derwent World Patents Index Database (London: Derwent Publications Ltd., 1996), special tabulations by Mogee Research & Analysis Associates under contract to the National Science Foundation.

Science & Engineering Indicators – 1998

[25]"Highly cited" here means the top 1 percent of international families in terms of the number of citations received. To adjust for the advantage countries with large numbers of international families would have on this indicator, a country's share of highly cited patents are divided by its share of total patent families.

[26]Operationally, this calculation involves counting the number of countries in a family in which a patent publication (i.e., a published patent application or an issued patent) exists. Patents in each family are weighted by an index based on the GDP in purchasing power parities at current U.S. dollars of the patent country. The index runs from 0 to 1.00, and U.S. GDP is set at 1.00.

Text table 6-8.
Robot technology: International patent families, highly cited patent families, and citation ratios, by priority country: 1990-94

Priority country	Number of international families	Number of highly cited international families[a]	Country share of total (percent)	Country share of highly cited (percent)	Citation ratio[b]
Total	1,719	18.0	100.0	100.0	1.0
United States	411	10.0	23.9	55.6	2.3
Japan	737	6.0	42.9	33.3	0.8
Germany	278	2.0	16.2	11.1	0.7
United Kingdom	162	0.0	9.4	0.0	0.0
France	72	0.0	4.2	0.0	0.0
South Korea	59	0.0	3.4	0.0	0.0

[a]An international patent family was considered highly cited if the number of citations it received ranked it within the top 1 percent compared with all other robot technology international patent families.

[b]A citation ratio of greater than 1.0 indicates that a country has a higher share of highly cited international patent families than would be expected based on its share of total families.

SOURCE: Derwent World Patents Index Database (London: Derwent Publications Ltd., 1996), special tabulations by Mogee Research & Analysis Associates under contract to the National Science Foundation.

Science & Engineering Indicators – 1998

Only the United States had more highly cited international patent families than would be expected—2.3 times—based on its level of activity (i.e., based on the total number of U.S. international robot technology families). None of the other countries studied produced the expected number of highly cited inventions. Specifically, Japan produced only about 80 percent of what might be expected based on the number of inventions it produced during this period, and Germany produced only about 70 percent of what was expected. Again, France, the United Kingdom, and South Korea—with nearly 300 international robot patent families among them—had no highly cited robot inventions during this period.

The United States thus appears to have contributed a disproportionate number of important robot inventions relative to its level of inventive activity. This circumstance also may suggest that even though Japan had a higher number of international robot inventions, U.S. inventions were more technologically important.

Mean International Patent Family Size. This indicator attempts to measure the perceived economic potential of a robot invention by calculating, for each international patent family, the number of countries in which patent protection is being sought, adjusted for market size. When mean international patent family size is calculated for each country's robot technologies, there is not as much separation in the scores as might be expected. (See text table 6-9.) U.S. inventions received the highest score and therefore have the highest level of perceived commercial value based on this measure. South Korean inventions received the lowest score. Since most inventions are first patented in the country in which the inventor resides, U.S. inventions have an advantage in this indicator due to the large size of the U.S. economy.[28] But European inventions also have the advantage of many commercial, locational, and historical ties that facilitate multiple-country patenting. Furthermore, the move toward European unification has encouraged wider patenting within Europe. Still, U.S. inventions scored slightly higher on average than did European robot inventions. Japan's robot inventions also scored well on this indicator, bolstered by the tendency of Japanese inventors to seek patent protection in large economies such as the United States and Germany (79 and 60 percent, respectively). South Korea scored remarkably well, but it too sought patent protection for most of its robot inventions in large markets like the United States (64 percent) and Japan (41 percent).

Genetic Engineering

For this study, genetic engineering is defined as recombinant DNA (rDNA) technology. It includes processes for isolation, preparation, or purification of DNA or RNA; DNA or RNA fragments and modified forms thereof; the introduction of foreign genetic material using vectors; vectors; use of hosts; and expression.[29] As used here, genetic engineering does not include monoclonal antibody technology.

[28]Because of its market size, the United States attracts most commercially important inventions; for this reason, data on U.S. patenting are often used to compare international inventiveness. To overcome differences in national patent systems, the European Commission chose U.S. patent data as a basis for comparing technological output performance of industrial R&D for member countries and stated, "The US is undoubtedly still the most important technological 'market' attracting all major inventions from across the world" (European Commission 1994).

[29]The trends discussed for genetic engineering technology are based on all genetic engineering international families in the Derwent World Patents Index Latest database, with priority applications in the six countries under study and basic patent publications from 1991 to 1997. These six countries accounted for over 85 percent of the total genetic engineering patent families.

Text table 6-9.
Robot technology: Number of international patent families and average international family size: 1990-94

Priority country	Number of families	Average international family size	Adjusted average international family size[a]
United States	411	7.9	1.6
France	162	8.8	1.4
Japan	737	4.6	1.3
United Kingdom	72	10.1	1.3
Germany	278	8.3	1.2
South Korea	59	2.1	1.0

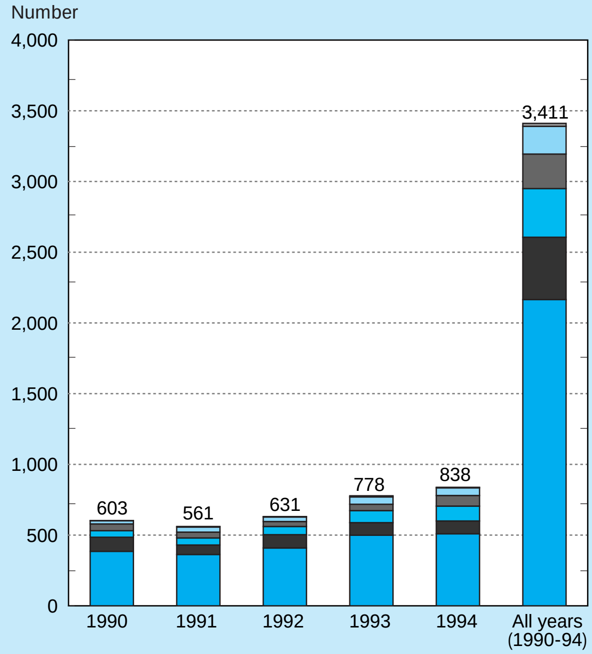
NOTE: Patent family size is determined by the number of countries for which patent protection is sought for a single invention.

[a]Patent family data weighted by an index based on gross domestic product measured in purchasing power parities at current U.S. dollars of the patent country. This weighting adjusts family size for the size of the national markets in which protection is being sought in an effort to better reflect the commercial potential of the invention.

SOURCE: Derwent World Patents Index Database (London: Derwent Publications Ltd., 1996), special tabulations by Mogee Research & Analysis Associates under contract to the National Science Foundation.

Science & Engineering Indicators – 1998

Figure 6-21.
Genetic engineering: Number of international patent families, by priority year and country



	1990	1991	1992	1993	1994	All years (1990-94)
South Korea	2	4	3	8	4	21
France	22	36	32	52	54	196
Germany	48	41	35	45	75	244
United Kingdom	46	50	58	85	105	344
Japan	100	67	94	89	91	441
United States	385	363	409	499	509	2,165

SOURCE: Derwent World Patents Index Database (London: Derwent Publications Ltd., 1996), special tabulations by Mogee Research & Analysis Associates under contract to the National Science Foundation.
Science & Engineering Indicators – 1998

International Patenting Activity. If the decade of the 1980s generally introduced genetically engineered products to the global marketplace, then the 1990s may become the decade when genetically engineered products come of age. Although slow compared to patenting in the previous decade, the number of international patent families grew steadily from 1991 to 1994, with the largest jump recorded in 1993. (See figure 6-21.) The United States is widely considered the global leader in the biotechnology field, and these data support that perception. The United States is the priority country (location of first patent application) for 63 percent of the internationally patented inventions created during the 1990-94 period; Japan follows with 13 percent, the United Kingdom with 10 percent, and Germany with 7 percent.

When the total number of foreign applications associated with each country's genetic engineering technology is considered, the United States continues to lead all other countries by a wide margin. The United States had more foreign patents than the other five countries combined, accounting for almost 64 percent of the nearly 42,000 foreign patents. The rankings and shares for the other five countries remain the same.

Highly Cited Genetic Engineering Inventions.[30] Out of the 3,411 international patent families in genetic engineering formed by the six countries during the 1990-94 period, only 39 were considered highly cited inventions. The United States, with about 63 percent of the total international patent families recorded during the period, also had the largest proportion of highly cited international patent families—59 percent. (See text table 6-10.) Japan, with 13 percent of the total families, had just 10 percent that were highly cited. The United States, Japan, Germany, and South Korea all produced fewer highly cited patents than expected based on their shares of patent families associated with this technology. The United Kingdom produced the expected number of highly cited inventions based on its share of the total genetic engineering inventions patented internationally (citation ratio equal to 1.0). The only country that exceeded expectations on this indicator was France. France, with far fewer patent families overall than the other countries examined, produced more than three times the number of important or highly cited patents as expected based on its level of activity.

Based on this indicator, the United States leads the other countries in terms of the volume of important (highly cited) genetic engineering inventions it produced during the period

[30]Operationally, this indicator included all international patent families with priority application dates from 1990 to 1994 with four or more citations.

Text table 6-10.
Genetic engineering: International patent families, highly cited patent families, and citation ratios, by priority country: 1990-94

Priority country	Number of international families	Number of highly cited international families[a]	Country share of total (percent)	Country share of highly cited (percent)	Citation ratio[b]
Total	3,411	39.0	100.0	100.0	1.0
United States	2,165	23.0	63.5	59.0	0.9
France	196	7.0	5.7	17.9	3.1
United Kingdom	344	4.0	10.1	10.3	1.0
Japan	441	4.0	12.9	10.3	0.8
Germany	244	1.0	7.2	2.6	0.4
South Korea	21	0.0	0.6	0.0	0.0

[a]An international patent family was considered highly cited if the number of citations it received ranked it within the top 1 percent compared with all other genetic engineering technology international patent families.

[b]A citation ratio of greater than 1.0 indicates that a country has a higher share of highly cited international patent families than would be expected based on its share of total international families.

SOURCE: Derwent World Patents Index Database (London: Derwent Publications Ltd., 1996), special tabulations by Mogee Research & Analysis Associates under contract to the National Science Foundation.

Science & Engineering Indicators – 1998

examined. While it fell slightly short (citation ratio of 0.9) of what might be expected given its share of overall patenting in this technology, the total number of highly cited patents produced by the United States in this important technology area is nevertheless noteworthy.

Mean International Patent Family Size. Patented genetic engineering inventions developed in Japan and Germany appear to be the most commercially valuable, on average, based on this measure, although the scores for each of the countries are similar. (See text table 6-11.) Japan has sought patent protection in 11 countries whose combined economies are equivalent to 1.6 times that of the United States (based on GDP); German-origin inventions average 14.7 countries with a combined GDP equal to 1.5 times that of the United States. Patented genetic engineering inventions originating in the United States rank third in perceived commercial exploitation potential. Inventions originating in France, South Korea, and the United Kingdom all trailed the United States based on this measure.

Text table 6-11.
Genetic engineering: Number of international patent families and average international family size: 1990-94

Priority country	Number of families	Average international family size	Adjusted average international family size[a]
Japan	441	11.3	1.6
Germany	244	14.7	1.5
United States	2,165	12.8	1.4
France	196	14.9	1.3
South Korea	21	10.0	1.3
United Kingdom	344	12.4	1.0

NOTE: Patent family size is determined by the number of countries for which patent protection is sought for a single invention.

[a]Patent family data weighted by an index based on gross domestic product measured in purchasing power parities at current U.S. dollars of the patent country. This weighting adjusts family size for the size of the national markets in which protection is being sought in an effort to better reflect the commercial potential of the invention.

SOURCE: Derwent World Patents Index Database (London: Derwent Publications Ltd., 1996), special tabulations by Mogee Research & Analysis Associates under contract to the National Science Foundation.

Science & Engineering Indicators – 1998

Advanced Ceramics

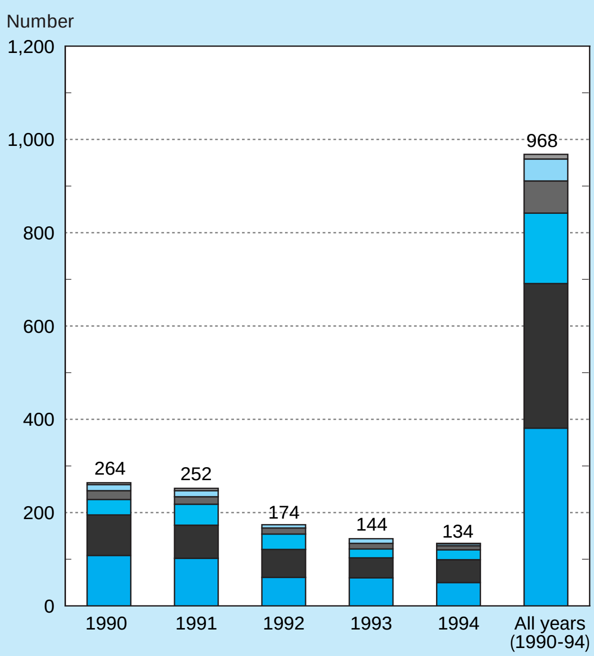
National technological positions in the broad field of advanced materials have been assessed through an examination of international patenting activity in advanced ceramics. For this study, advanced ceramics are defined as ceramics (i.e., inorganic, nonmetallic solids) with compositions not usually found in traditional ceramics. These compositions include oxides, carbides, nitrides, and borides, as well as aluminate, titanate, zirconia, and modified silicates. The six countries analyzed represent approximately 90 percent of total international patent family activity by all countries in this technology.

International Patenting Activity. During the 1990-94 period, these six countries generated a total of 968 international patent families in the field of advanced ceramics. Annual formation of international patent families varied from a high of 264 in 1990 to 134 in 1994, which is the last priority year for which complete data are available.

Japan and the United States lead all other nations in the formation of international patent families involving advanced ceramics technology. Together they accounted for over 70 percent of the total formed in the five-year period examined. (See figure 6-22.) Japan held 39 percent of the total families formed (with 381 international families) over the period studied; the United States held 32 percent (with 310 international families). Germany, France, and the United Kingdom trailed with 16, 7, and 5 percent of the total, respectively. South Korea held 1 percent of the international patent families in this technology.

When the total number of foreign applications associated with each country's advanced ceramics technology is considered, the United States and Japan switch places, with the United States taking the lead in terms of total number of foreign patents sought for advanced ceramics technology. Out of a total of 7,025 advanced ceramics foreign patents generated from priority applications filed by the six countries during the 1990-94 period, the United States generated 40 percent (2,811 patents); Japan generated 24 percent (1,669 patents).

Figure 6-22.
Advanced ceramics technology: Number of international patent families, by priority year and country



	1990	1991	1992	1993	1994	All years (1990-94)
South Korea	4	5	0	0	1	10
United Kingdom	13	13	7	10	4	47
France	19	16	13	12	9	69
Germany	33	45	33	19	21	151
United States	87	71	60	43	49	310
Japan	108	102	61	60	50	381

SOURCE: Derwent World Patents Index Database (London: Derwent Publications Ltd., 1996), special tabulations by Mogee Research & Analysis Associates under contract to the National Science Foundation.

Science & Engineering Indicators – 1998

Highly Cited Advanced Ceramics Inventions.[31] Out of the 968 international patent families formed during the 1990-94 period, only 23 were highly cited. Japan generated the greatest number of international patent families in this technology area during the same period, but the United States had the greatest number of highly cited inventions with 15 (or 65 percent of all highly cited international patent families). (See text table 6-12.) Japan was second with four. When each country's number of highly cited international patent families is adjusted to account for its overall volume of international patenting in this technology (citation ratio), the United States again leads all six nations. The United States had a citation ratio of 2.0—that is, twice as many highly cited international patent families as would be expected given its share of total families during the period. Japan's citation ratio, 0.4, suggests that the four highly cited international families it produced during this period were below expectations, given the total number of international patent families the country generated. The United Kingdom had only two highly cited international families, but exceeded expectations in this indicator with a citation ratio of 1.8. France and Germany each had one highly cited international patent family, falling below expectations given their share of total families in this technology.

Mean International Patent Family Size. The advanced ceramics inventions with the highest perceived foreign market potential, on average, were produced in France; these were closely followed by those produced in the United States. (See text table 6-13.) The United States also had the second largest number of international patent families for the period examined. Japan, the most prolific inventor of world-class advanced ceramics technologies during the 1990-94 period, trailed the United States and the large European nations in terms of average commercial potential for each invention. South Korea also trailed the leaders, but still made an impressive showing in this technology area, providing yet another indication of its progress in developing science-based technologies (see NSB 1993, p. 185).

Taken together, these indicators suggest strong U.S. inventive activity in advanced ceramics technology. While producing the second largest number of international patent families in this category during the period studied, U.S. inventions were the most highly cited and had nearly the highest average commercial potential when compared with inventive activity in the other five nations.

Summary

Based on this examination of international patenting, the U.S. S&T enterprise is producing inventions in important technologies that are able to be patented around the world. The U.S. lead in genetic engineering was most evident from this collection of international patenting indicators, but U.S. inventors also made a strong showing in robot technologies, especially in 1994.

[31] Operationally, this indicator included all families with priority application dates from 1990 to 1994 with four or more citations.

Text table 6-12.
Advanced ceramics technology: International patent families, highly cited patent families, and citation ratios, by priority country: 1990-94

Priority country	Number of international families	Number of highly cited international families[a]	Country share of total (percent)	Country share of highly cited (percent)	Citation ratio[b]
Total	968	23.0	100.0	100.0	1.0
United States	310	15.0	32.0	65.2	2.0
Japan	381	4.0	39.4	17.4	0.4
Germany	151	1.0	15.6	4.3	0.3
France	69	1.0	7.1	4.3	0.6
United Kingdom	47	2.0	4.9	8.7	1.8
South Korea	10	0.0	1.0	0.0	0.0

[a]An international patent family was considered highly cited if the number of citations it received ranked it within the top 1 percent compared with all other advanced ceramics technology international patent families.

[b]A citation ratio of greater than 1.0 indicates that a country has a higher share of highly cited international patent families than would be expected based on its share of total international families.

SOURCE: Derwent World Patents Index Database (London: Derwent Publications Ltd., 1996), special tabulations by Mogee Research & Analysis Associates under contract to the National Science Foundation.

Science & Engineering Indicators – 1998

Text table 6-13.
Advanced ceramics technology: Number of international patent families and average international family size: 1990-94

Priority country	Number of families	Average international family size	Adjusted average international family size[a]
France	69	11.2	1.9
United States	310	9.8	1.8
United Kingdom	47	11.6	1.7
Germany	151	9.7	1.7
Japan	381	5.3	1.6
South Korea	10	3.2	1.3

NOTE: Patent family size is determined by the number of countries for which patent protection is sought for a single invention.

[a]Patent family data weighted by an index based on gross domestic product measured in purchasing power parities at current U.S. dollars of the patent country. This weighting adjusts family size for the size of the national markets in which protection is being sought in an effort to better reflect the commercial potential of the invention.

SOURCE: Derwent World Patents Index Database (London: Derwent Publications Ltd., 1996), special tabulations by Mogee Research & Analysis Associates under contract to the National Science Foundation.

Science & Engineering Indicators – 1998

Venture Capital and High-Technology Enterprise

One of the most serious challenges to new entrepreneurs in the innovation process is capital—or the lack thereof. Venture capitalists typically make investments in small, young companies that may not have access to public or credit-oriented institutional funding. Venture capital investments can be long term and high risk, and may include hands-on involvement by the venture capitalist in the firm. Venture capital thus can aid the growth of promising small companies and facilitate the introduction of new products and technologies, and is an important source of funds used in the formation and expansion of small high-tech companies. This section examines venture capital disbursements by stage of financing and by technology area in the United States and Europe.

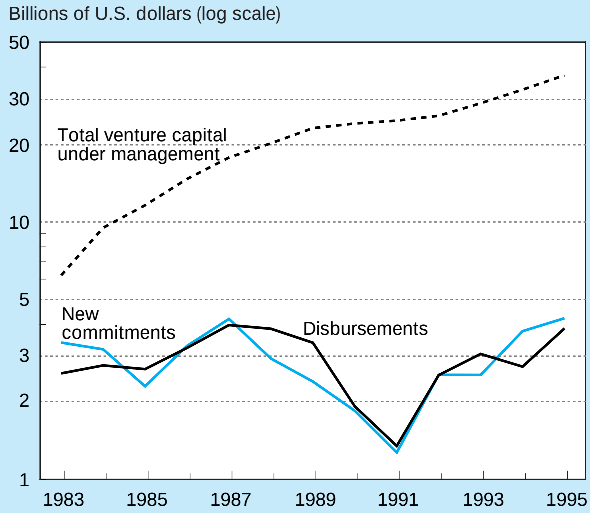
U.S. Venture Capital Industry

The pool of capital managed by venture capital firms grew dramatically during the 1980s as venture capital emerged as a truly important source of financing for small innovative firms. (See figure 6-23 and appendix table 6-19.) By 1989, the capital managed by venture capital firms totaled $23.2 billion, up from an estimated $3.0 billion in 1980. The number of venture capital firms also grew during the 1980s—from around 448 in 1983 to 670 in 1989.

In the early 1990s, the venture capital industry experienced a recession of sorts, as investor interest waned and the amount of venture capital disbursed to companies declined—especially compared to the extensive venture capital activity of the late 1980s. The number of firms managing venture capital also declined during the 1990s. But the slowdown was short-lived; investor interest picked up during 1992, and disbursements began to rise again. Both investor interest and venture capital disbursements have continued to grow through 1995. The latest data show total venture capital under management rising to $37.2 billion in 1995, up from $32.7 billion in 1994 and $28.9 billion in 1993.

The number of venture capital firms in the United States did not rebound to the peak of 1989 (670), but after several

Figure 6-23.
U.S. venture capital: Total under management, annual commitments, and disbursements



See appendix table 6-19. *Science & Engineering Indicators – 1998*

years of firm rationalization, the number rose to 610 venture capital firms in 1995 from the 591 operating in 1994. California, Massachusetts, and New York together account for nearly 65 percent of venture capital resources. The top 10 states account for over 95 percent. It appears that venture capital firms tend to cluster around locales considered to be "hotbeds" of technological activity, as well as in states where large amounts of R&D are performed.

Venture Capital Commitments and Disbursements

Several years of high returns on venture capital investments have stimulated increased investor interest. This interest soared from 1993 to 1995, with new commitments reaching $4.2 billion in 1995, the largest one-year increase in venture capital funds. Pension funds remain the single largest source for new funds, supplying nearly 40 percent of committed capital. Endowments/foundations are the next largest source, supplying 23 percent of committed capital in 1995. (See appendix table 6-20.)

Starting in 1994, new capital raised exceeded capital disbursed by the venture capital industry, thereby creating surplus funds available for investments in new or expanding innovative firms. Thus far in the 1990s, firms producing computer software or providing computer-related services received the largest share of new disbursements. (See figure 6-24 and appendix table 6-21.) In 1991, software companies received 25 percent of all new venture capital disbursements, twice the share going to computer hardware companies and three times the share going to biotechnology companies. In 1995, software companies continued to attract the largest share of venture capital. Medical/health-care-related companies have also attracted large amounts of venture capital during the 1990s, and edged out software companies for the lead in 1994. Other industries that received substantial amounts of venture capital in 1995 were telecommunications companies and consumer-related companies (e.g., leisure products, retailing, etc.).

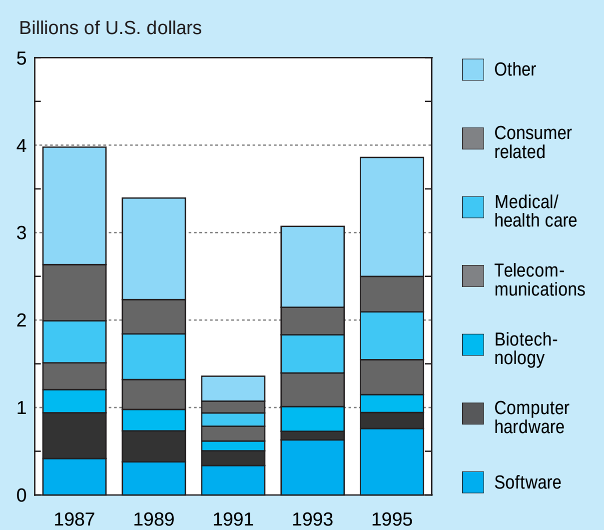
Venture Capital Investments by Stage of Financing

The investments made by venture capital firms may be categorized by the stage at which the financing is provided:[32]

- ♦ **Seed financing**—usually involves a small amount of capital provided to an inventor or entrepreneur to prove a concept. It may support product development but rarely is used for marketing.
- ♦ **Startup financing**—provides funds to companies for use in product development and initial marketing. This type of financing usually is provided to companies that are just getting organized or that have been in business just a short time but have not yet sold their product in the marketplace. Generally, such firms have already assembled key management, prepared a business plan, and made market studies.
- ♦ **First-stage financing**—provides funds to companies that have exhausted their initial capital and need funds to initiate commercial manufacturing and sales.
- ♦ **Expansion financing**—includes working capital for the initial expansion of a company, funds for either major

[32]The financing stage definitions presented here are by Venture Economics (1996), appendix C.

Figure 6-24.
U.S. venture capital disbursements, by industry category



See appendix table 6-21. *Science & Engineering Indicators – 1998*

growth expansion (involving plant expansion or marketing) or development of an improved product, and financing for a company expecting to go public within six months to a year.

- **Management/leveraged buyout financing—**includes funds to enable operating management to acquire a product line or business from either a public or private company.
- **Turnaround financing—**provides financing to a company at a time of operational or financial difficulty, with the intention of turning the company around or improving its performance.

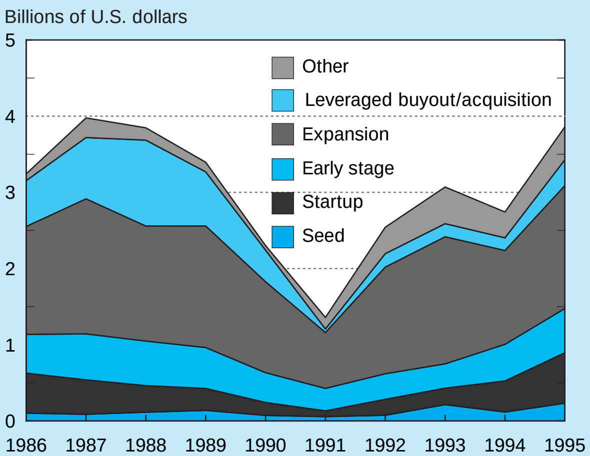
The first three may be referred to as early stage financing and the remaining three as later stage financing.

An examination of U.S. venture capital disbursements to companies since 1986 clearly shows that most of the funds are directed to later stage investments. Over the past 10 years, later stage investments captured between 62 and 76 percent of venture capital disbursements, with the high and low points both reached in the 1990s. (See figure 6-25 and appendix table 6-22.) Capital for company expansions attracted by far the most investor interest.

According to these data, very little venture capital goes to the struggling inventor or entrepreneur trying to prove a concept or to product development. Over the past 10 years, such seed money never accounted for more than 7 percent of all venture capital disbursements, and most often represented between 3 and 4 percent of the annual totals.[33]

[33]A study of new firms located in the Southwestern United States discovered that many of these firms were able to obtain substantial amounts of initial capital through strategic alliances with more established firms (Carayannis, Kassicieh, and Radosevich 1997). In that study, embryonic firms raised over $2 million, on average, in early stage capital through such strategic alliances.

Figure 6-25.
U.S. venture capital disbursements, by stage of financing



See appendix table 6-22. *Science & Engineering Indicators – 1998*

Europe's Venture Capital Industry

As in the United States, venture capitalists in Europe are attracted to young, small (under 500 employees), fast-growing companies in need of capital and management expertise. Europe now has venture-capital-backed investments all across the continent, including investments in many of the transitioning countries in Central and Eastern Europe. Data compiled by the European Venture Capital Association tracking venture capital activity in 17 countries record over 5,000 separate investments in 1996, with total disbursements exceeding $8.5 billion—an 18 percent increase over 1995.[34] (See text table 6-14.) The United Kingdom leads Europe in both the number of venture-backed investments made and the amount invested in British companies during 1996 (33 percent and 44 percent, respectively). France, Germany, and the Netherlands follow, in that order. Together with the United Kingdom, they accounted for three-fourths of all European venture capital disbursed in 1996.

While computer-related and biotechnology companies in the United States garner the lion's share of U.S. venture capital, the types of firms attracting venture capital in Europe are less technology intensive. Europe has long held a reputation for excellence in industrial machinery and equipment, fashion, and leisure products (e.g., sporting goods).These same industries are among the top recipients of European venture capital. More than 30 percent of venture capital investments (both in number and as a percentage of the total capital distributed in 1995 and 1996) were made in companies providing industrial products such as machine tools, pollution and recycling equipment, and high-fashion clothing and other consumer products. By comparison, European computer-related companies received 7 percent of the venture capital distributed in 1995 and 5 percent in 1996. European biotech companies received even less attention, although both the number and size of the investments in this industry increased in 1996 over the previous year.

European venture capitalists, like their American counterparts, direct only a small portion of capital disbursements as seed money or startup capital. Investments for expanding an existing company's productive capacity, helping a company add a new product line, or enabling a company to acquire an existing business—later stage investments—account for about 85 percent of European venture capital disbursements. For the past five years (1992 to 1996), early stage investments (as seed or startup capital) stayed below 7 percent. In fact, seed money, often used to finance research or concept development, averaged less than 1 percent from 1992 to 1995; in 1996, startup capital for product development and initial marketing reached its highest point in five years, when it represented about 6 percent of venture capital disbursements. (See figure 6-26.)

[34]Data reported on venture capital investments in Europe include management buyouts, management buyins, and other later stage investments not covered in the previous discussion on venture capital investment trends in the United States.

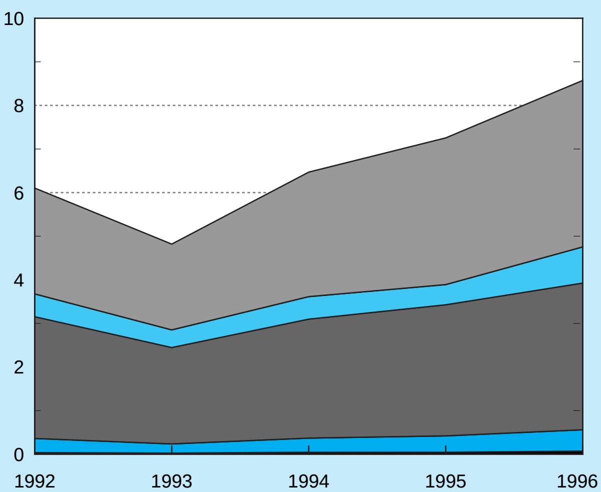
Text table 6-14.
Number and amount of European venture capital disbursements

	1995 investments		1996 investments	
	Number	Millions of U.S. $	Number	Millions of U.S. $
European total	4,955	7,254.2	5,181	8,573.4
United Kingdom	1,716	3,443.0	1,715	3,774.0
France	994	1,113.1	1,186	1,078.0
Germany	762	871.1	769	907.9
Netherlands	280	610.8	320	752.0
Italy	220	330.9	198	647.6
Sweden	78	112.5	172	533.3
Spain	218	213.2	158	245.1
Switzerland	29	62.8	32	161.3
Belgium	132	145.2	158	138.4
Norway	163	156.0	154	105.4
Finland	114	44.5	111	50.8
Ireland	33	24.9	65	48.3
Portugal	137	71.9	74	43.2
Denmark	48	40.5	38	43.2
Greece	13	10.5	23	40.6
Austria	4	1.3	4	1.3
Iceland	14	1.3	4	1.3

SOURCE: European Venture Capital Association, *1997 Yearbook* (Zavenstem, Belgium: 1997).

Science & Engineering Indicators – 1998

Figure 6-26.
European venture capital disbursements, by stage of financing



Disbursements in millions of U.S. dollars

	1992	1993	1994	1995	1996
Buyout	2,427.45	1,967.28	2,856.04	3,364.20	3,818.14
Replacement capital	523.13	405.17	516.25	463.04	829.15
Expansion	2,792.21	2,210.85	2,728.76	3,007.11	3,364.84
Startup	325.82	210.78	324.74	375.40	490.12
Seed	35.05	24.59	44.01	44.47	69.84
Total	6,103.66	4,818.67	6,469.80	7,254.22	8,572.09

NOTE: The financing stages used to characterize European venture capital disbursements differ somewhat from the U.S. stages used.

SOURCE: European Venture Capital Association, *1997 Yearbook* (Zavenstem, Belgium: 1997).

Science & Engineering Indicators – 1998

New High-Tech Exporters

The previous sections identified several nations that have made tremendous technological leaps forward over the past decade. Some of these countries appear to be well-positioned to play even more important roles in technology development in the near future based on their often large and continuing investments both in science and engineering education and R&D. However, their level of participation may also hinge on other factors, among them political stability, access to capital, and the ability to complete a level of infrastructure that can support technological and economic advancement.

This section presents an assessment of future national competitiveness in high-technology industries for newly industrialized economies in Asia and in three transitioning economies—Hungary, Poland, and Russia. This competitiveness is gauged through scores on the following leading indicators:

- **National orientation**—evidence that a nation is taking directed action to achieve technological competitiveness. These actions might be explicit and/or implicit national strategies involving cooperation between the public and private sectors.
- **Socioeconomic infrastructure**—the social and economic institutions that support and maintain the physical, human, organizational, and economic resources essential to the functioning of a modern, technology-based industrial nation. Evidence of this type of infrastructure might be dynamic capital markets, upward trends in capital formation, rising levels of foreign investment, and national investments in education.

- **Technological infrastructure—**the social and economic institutions that contribute directly to a nation's capacity to develop, produce, and market new technology. Evidence of a supportive technological infrastructure might include the existence of a system for the protection of intellectual property rights, the extent to which R&D activities relate to industrial application, a nation's competency in high-tech manufacturing, and a nation's capability to produce qualified scientists and engineers from the general population.
- **Productive capacity—**the physical and human resources devoted to manufacturing products, and the efficiency with which those resources are used. A nation's productive capacity for future high-tech production can be assessed by examining its current level of high-tech production, including the quality and productivity of its labor force, the presence of skilled labor, and the existence of innovative management practices.

These four indicators were designed to identify countries that have the potential to become more important exporters of high-technology products over the next 15 years. This section analyzes 12 economies using these indicators: 9 within Asia (Singapore, South Korea, Taiwan, China, India, Indonesia, Malaysia, the Philippines, and Thailand); 2 Central European nations (Hungary and Poland); and Russia.[35]

Because Singapore, South Korea, and Taiwan have already shown impressive capabilities as exporters of high-technology products, they are often referred to as newly industrialized economies. The six remaining Asian economies are less developed technologically and are considered emerging Asian economies in this section. The three Central and Eastern European nations—Hungary, Poland, and Russia—are actively pursuing market-based reforms and are collectively referred to as transitioning economies. For this model of indicators, the Asian newly industrialized economies become the benchmark to compare expectations and technological capabilities for the other nine.[36]

National Orientation

The national orientation indicator attempts to identify those nations whose business, government, and cultural orientation encourage high-technology development. This indicator was constructed using information from a survey of international experts and published data. The survey asked the experts to rate national strategies promoting high-tech development, social influences favoring technological change, and entrepreneurial spirit. Published data were used to rate each nation's risk factor for foreign investment over the next five years (see Frost and Sullivan 1996).

[35]See Porter and Roessner (1991) for details on survey and indicator construction; see Roessner, Porter, and Xu (1992) for information on the validity and reliability testing the indicators have undergone.

[36]Although not discussed in this section, indicator scores for Argentina, Brazil, Mexico, Venezuela, and South Africa are presented in appendix table 6-23.

The newly industrialized Asian economies posted the highest overall scores on this indicator, with Taiwan just edging out Singapore. (See figure 6-27 and appendix table 6-23.) Entrepreneurial spirit was rated much higher for Taiwan than for Singapore. This rating, derived from expert opinion, elevated Taiwan's overall score above Singapore's—despite Taiwan scoring lower than Singapore on each of the other components. While South Korea scored lower than the other two Asian "tigers" on each of the components that make up this indicator, its composite score was largely compromised by its rating as a riskier place for foreign investment than either Taiwan or Singapore.

Malaysia's national orientation toward achieving future technological competitiveness was rated far above the other emerging Asian economies and the transitioning economies in Central Europe and Russia. Across the full range of variables considered, Malaysia's scores were consistently and significantly higher than the other countries in this second group and were well within the range of scores accorded the more advanced newly industrialized Asian economies. The Philippines also scored well, with strong scores in each of the indicator components, elevating it to the second highest score among the emerging Asian economies and other transitioning economies in Central Europe.

Scores tended to converge for the remaining Asian and Central European economies, although each country's composite score is built on different strengths. Scores for Poland and Hungary were slightly higher than those for China and Thailand. Published data rated the two Central European nations a better risk for foreign investment than China, and the surveyed experts gave an edge to Poland and Hungary over Thailand on "entrepreneurial spirit."

Russia received the lowest composite score of the 12 economies examined. Two variables contributed to this standing: Russia was considered a riskier or less attractive site for foreign investment than the other countries, and the experts accorded Russia a low score on its entrepreneurial spirit.

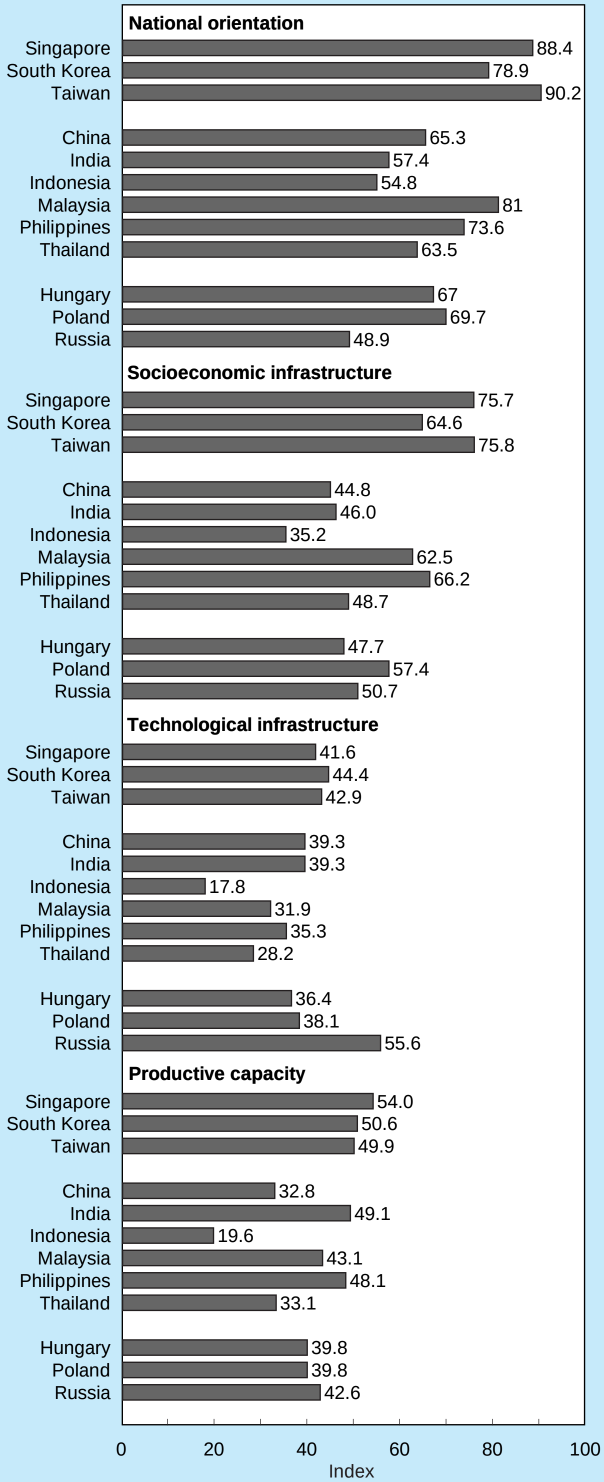
Socioeconomic Infrastructure

This indicator assesses the underlying physical, financial, and human resources needed to support modern technology-based nations. It was built from published data on population percentages in secondary schools and in schools of higher education[37] and from survey data evaluating the mobility of capital and the extent to which foreign businesses are encouraged to invest and/or do business in that country.

Taiwan and Singapore are in a virtual tie and once again received the highest scores among the group of newly industrialized and emerging economies. In addition to strong track records on general and higher education, Taiwan and

[37]The Harbison-Myers Skills Index (which measures the percentage of population attaining secondary and higher educations) was used for these assessments. See World Bank (1996).

Figure 6-27.
Leading indicators of technological competitiveness: 1996



NOTE: Scores were normalized to median values of zero based on raw scores for 30 countries included in the study.

See appendix table 6-23. *Science & Engineering Indicators – 1998*

Singapore reflect high expert ratings for variables comparing the mobility of capital and for their encouragement of foreign investment. (See figure 6-27.) South Korea's overall indicator score trailed these two leaders, especially with regard to the two expert-derived variables.

Among the emerging and transitioning economies, the Philippines once again scored surprisingly well, outscoring even Malaysia. The rating for the Philippine socioeconomic infrastructure was bolstered by a stronger showing in the published education data and in the experts' higher opinion of mobility of capital in the Philippines.

Indonesia received the lowest composite score of the 12 economies examined. It was held back by low marks on two of the three variables: educational attainment—in particular, enrollments in tertiary education—and its encouragement of foreign-owned business and investment.

Technological Infrastructure

Five variables were used to develop this indicator, which evaluates the institutions and resources that contribute to a nation's capacity to develop, produce, and market new technology. This indicator was constructed using published data on the number of scientists in R&D; published data on national purchases of electronic data processing equipment; and survey data that asked experts to rate the nation's capability to train citizens locally in academic S&E, the ability to make effective use of technical knowledge, and the linkages of R&D to industry.

Russia received the highest composite score of the group of newly industrialized or transitioning economies examined here. (See figure 6-27.) Russia's score on this indicator was elevated by its large number of trained scientists and engineers, the size of its research enterprise, and its contribution to scientific knowledge—especially as compared with the smaller, less populous nations in Asia and Central Europe. Russia's composite score was more similar to mid-level Western European scores on this indicator. (See appendix table 6-23.) Poland also scored well, bolstered more by experts' rating of the quality of that country's scientists and engineers and its capacity to train new scientists and engineers, rather than on the sheer number of those professionals residing within the country.

The three Asian tigers—Singapore, South Korea, and Taiwan—compiled similar scores. Singapore scored relatively well vis-à-vis the other Asian tigers, given its small population.

The population effect shows up again in the scores of the remaining countries analyzed here. China and India both scored well, leading the other emerging and transitioning economies. Indonesia's large population, however, did not save it from the bottom ranking. It earned low scores on each of the variables making up this indicator.

Productive Capacity

This indicator evaluates the strength of a nation's current, in-place manufacturing infrastructure as a baseline for assessing its capacity for future growth in high-tech activities. It factors in expert opinion on the availability of skilled labor, numbers of indigenous high-tech companies, and management capabilities, combined with published data on current electronics production in each economy.

Singapore's productive capacity scored highest among the three Asian tigers, surpassing South Korea and Taiwan by virtue of experts' high opinion of this country's pool of labor and management personnel. (See figure 6-27.) India and the Philippines both scored quite high—in fact, their composite scores were closer to Taiwan's than to any in the group of emerging or transitioning economies. India's score was elevated by its comparatively large electronics manufacturing industry and—once again—by its tradition of training its students in science and engineering. The Philippines' score also stands out. As with Singapore, experts gave high marks to the pool of skilled labor and management talent in the Philippines. That country's scores were on a par with those received by the three Asian tigers. Although Indonesia's score for production of electronics products—this indicator's published data variable—was between that of India and the Philippines, its scores from experts rating the quality of labor and management were very low.

This model of indicators provides a systematic approach for comparing future technological capability on an even wider set of nations than might be available using other indicators. The results highlight a broadening of the group of nations that may compete in high-tech markets in the future, while also giving perspective to the large differences between several of the emerging and transitioning economies and those considered newly industrialized.

Summary: Assessment of U.S. Technological Competitiveness

This chapter brings together a collection of indicators that contrast and compare national technological competitiveness across a broad range of important technological areas. Based on the various indicators of technology development and market competitiveness examined, the United States continues to lead or be among the leaders in all technology areas. Advancements in information technologies (computers and telecommunications products) continue to influence new technology development and to dominate technical exchanges between the United States and its trading partners.

Asia's status as both a consumer and developer of high-tech products has been enhanced by the technological development taking place in the newly industrialized Asian economies—in particular, Taiwan and South Korea—and in emerging and transitioning economies such as Malaysia, China, and the Philippines. Asia's influence in the marketplace seems likely to expand in the future as other technologically emerging Asian nations join Japan as both technology producers and consumers.

Recently, several Asian nations have faced turmoil in their banking systems and capital markets. It is unclear how these developments will affect Asian economies and S&T capabilities.

The current strong position of the United States as the world's leading producer of high-tech products reflects its success both in supplying a large home-based market as well as in serving foreign markets. In addition to the nation's long commitment to investments in science and technology, this success in the international marketplace may be in part a function of scale effects derived from serving this large, demanding domestic market; it may be further aided by the U.S. market's openness to foreign competition. In the years ahead, these same market dynamics may also benefit a more unified Europe and/or a rapidly developing Asia and complement their investments in science and technology.

References

Abbott, T.A., III. 1991. "Measuring High Technology Trade: Contrasting International Trade Administration and Bureau of Census Methodologies and Results." *Journal of Economic and Social Measurement* 17: 17-44.

Abramovitz, M. 1986. "Catching Up, Forging Ahead, and Falling Behind." *Journal of Economic History* 46: 385-406.

Albert, M.B., D. Avery, F. Narin, and P. McAllister. 1991. "Direct Validation of Citation Counts as Indicators of Industrially Important Patents." *Research Policy* 20: 251-59.

Carpenter, M.P., F. Narin, and P. Woolf. 1981. "Citation Rates to Technologically Important Patents." *World Patent Information* 1981: 160-63.

Carayannis, E., S. Kassicieh, and R. Radosevich. 1997. "Financing Technological Entrepreneurship: The Role of Strategic Alliances in Procuring Early Stage Seed Capital." Paper presented at Portland International Conference on Management of Engineering and Technology, Portland, OR, July 27-31. Available from <<http://www.emp.pdx.edu/picmet/picmet.html>>.

Chakrabarti, A. 1991. "Competition in High Technology: Analysis of Patents of the United States, Japan, the United Kingdom, France, West Germany and Canada." *IEEE Transactions in Engineering Management* 38 (February): 78-84.

CHI Research Newsletter. 1997. Vol. V, No. 1 (March).

Claus, P., and P.A. Higham. 1982. "Study of Citations Given in Search Reports of International Patent Applications Published Under the Patent Cooperation Treaty." *World Patent Information* 4:105-9.

Council on Competitiveness. 1994. *Science in the National Interest*. Washington, DC.

———. 1996. *Endless Frontier, Limited Resources: U.S. R&D Policy for Competitiveness*. Washington, DC.

Corporate Technology Information Services, Inc. 1997. *Corporate Technology Directory 1997*. Rev. 12.3. Wellesley Hills, MA.

Derwent World Patents Index Database. 1996. London: Derwent Publications Ltd.

European Commission. 1994. *The European Report on Science and Technology Indicators 1994*. Brussels.

European Venture Capital Association. 1997. *1997 Yearbook*. Zavenstem, Belgium.

Faust, K. 1984. "Patent Data as Early Indicators of Technological Position of Competing Industrialized Countries." Paper translated by U.S. Patent and Trademark Office. PTO-1265. Washington, DC.

Frost & Sullivan. 1996. "Political Risk Letter." Political Risk Services, International Business Communications.

Greenwald, D., and Associates, eds. 1984. *The Concise McGraw-Hill Dictionary of Modern Economics*, 3rd ed. New York: McGraw-Hill.

Griliches, Z. 1990. "Patent Statistics as Economic Indicators: A Survey." *Journal of Economic Literature* 28 (December): 1661-707.

Hatzichronoglou, T. 1996. "Globalization and Competitiveness: Relevant Indicators." Report prepared for Organisation for Economic Co-operation and Development. OECD/GD(96)43. Paris: OECD.

Kim, L. 1997. *Imitation to Innovation: The Dynamics of Korea's Technological Learning*. Boston: Harvard Business School Press.

Mansfield, E. 1991. "Academic Research and Industrial Innovation." *Research Policy* 20, No. 1 (February): 1-12.

Mogee, M.E. 1991. *Technology Policy and Critical Technologies: A Summary of Recent Reports*. Washington, DC: National Academy of Engineering.

———. 1993. "International Patent Indicators of U.S. Position in Critical Technologies." Report prepared under National Science Foundation Contract No. SRS-9223041. Arlington, VA.

Mogee Research & Analysis Associates. 1997. "SGER: Comparing Assessments of National Position in Key Science & Technology Fields." Report prepared under National Science Foundation SGER Grant No. SRS-9618668. Washington, DC.

Mowery, D.C., and N. Rosenberg. 1993. "Chapter 2." In R.R. Nelson, ed., *National Innovation Systems*. New York: Oxford University Press.

Nadiri, I. 1993. *Innovations and Technological Spillovers*. NBER Working Paper No. 4423. Boston: National Bureau of Economic Research.

Narin, F., and D. Olivastro, 1988. "Technology Indicators Based on Patents and Patent Citations." In *Handbook of Quantitative Studies of Science and Technology*. Holland: Elsevier Science Publishers B.V.

Narin, F., K. Hamilton, and D. Olivastro. 1997. "The Increasing Linkage Between U.S. Technology and Public Science." *Research Policy* 26, No. 3 (December): 317-30.

National Critical Technologies Review Group. March 1995. *National Critical Technologies Report*. Washington, DC.

National Research Council (NRC). 1995. "The Effects of Technology and Innovation on Firm Performance and Employment." Proceedings of May 1-2, 1995, conference. Washington, DC: National Academy of Sciences.

National Research Council, Hamburg Institute for Economic Research, and Kiel Institute for World Economics. 1996. *Conflict and Cooperation in National Competition for High-Technology Industry*. Washington, DC: National Academy Press.

National Science Board (NSB). 1991. *Science & Engineering Indicators—1991*. NSB 91-1. Washington, DC: U.S. Government Printing Office.

———. 1993. *Science & Engineering Indicators—1993*. NSB 93-1. Washington, DC: U.S. Government Printing Office.

National Science Foundation (NSF), Science Resources Studies Division. 1995. *Asia's New High-Tech Competitors*. NSF 95-309. Arlington, VA.

Organisation for Economic Co-operation and Development (OECD). 1993. "Technology Diffusion: Tracing the Flows of Embodied R&D in Eight OECD Countries." DSTI/EAS (93) 5 Rev.1. Paris.

———. 1995. *Purchasing Power Parities and Real Expenditures, 1993. Volume 1, EKS Results*. Paris.

———. 1996. Structural Analysis Database for Industrial Analysis (STAN). Paris.

———. 1997. Analytical Business Enterprise R&D Database (ANBERD). Paris.

Pavitt, K. 1985. "Patent Statistics as Indicators of Innovative Activities: Possibilities and Problems." *Scientometrics* 7: 77-99.

Pearce, David. 1983. *The Dictionary of Modern Economics*. Cambridge: MIT Press.

Porter, A.L., and J.D. Roessner. 1991. *Indicators of National Competitiveness in High Technology Industries*. Final report to the Science & Engineering Indicators Studies Group, National Science Foundation, two volumes. Atlanta: Georgia Institute of Technology.

Roessner, J.D. 1992. *The Capacity for Modernization Among Selected Nations of Asia and the Pacific Rim*.

Roessner, J.D., A.L. Porter, and H. Xu. 1992. "National Capacities to Absorb and Institutionalize External Science and Technology." *Technology Analysis & Strategic Management* 4, No. 2.

Roessner, J.D., A.L. Porter, N. Newman, and H. Xu. 1997. *1996 Indicators of Technology-Based Competitiveness of Nations, Summary Report*. Prepared under National Science Foundation Purchase Order No. D22588X-00-0. Atlanta: Georgia Institute of Technology.

Romer, P.M. 1996. "Why, Indeed in America? Theory, History, and the Origins of Modern Economic Growth." *American Economic Review* 86, No. 2 (May).

Scherer, M. 1992. "Research on Patents and the Economy: The State of the Art." Paper presented at the 1st European Patent Office-IFO Workshop, Munich.

Souder, W.E. 1995. “The Evolution and Transfer of National Technologies: A Conceptual Model With Comparative Studies.” *Journal of Scientific & Industrial Research* 54 (April): 231-42.

Tassey, G. 1995. *Technology and Economic Growth: Implications for Federal Policy*. NIST Planning Report 95-3. Washington, DC: U.S. Department of Commerce.

Tyson, L.D. 1992. *Who's Bashing Whom: Trade Conflict in High-Technology Industries*. Washington, DC: Institute for International Economics.

U.S. Bureau of the Census, Foreign Trade Division. 1997. Data available from <<http://www.fedstats.gov>>.

U.S. Bureau of Economic Analysis. 1996. *Survey of Current Business* 76, No. 11 (November).

U.S. Bureau of Labor Statistics, Office of Productivity and Technology. 1997. “Comparative Real Gross Domestic Product Per Capita and Per Employed Person, Fourteen Countries, 1960-1995.” Washington, DC.

U.S. Department of Commerce. 1995. *U.S. Jobs Supported by Goods and Services Exports, 1983-92*. Washington, DC.

U.S. Office of Science and Technology Policy (U.S. OSTP). 1995. *National Critical Technologies Report*. Washington, DC: National Critical Technologies Panel.

———. 1997. *Science & Technology Shaping the Twenty-First Century*. Washington, DC: Executive Office of the President.

U.S. Patent and Trademark Office. 1996. *Patenting Trends in the United States, 1963-95*. Washington, DC.

U.S. Patent and Trademark Office, Office of Information Systems, TAF Program. 1996. *Country Activity Index Report, Corporate Patenting 1995*. Prepared for the National Science Foundation. Washington, DC.

Venture Economics. 1996. *1996 Venture Capital Annual Review*. Boston.

WEFA/ICF Global Industry Service. 1997. Database. Eddystone, PA: WEFA Group.

World Bank. 1996. *World Development Report 1996*. New York: Oxford University Press.

World Intellectual Property Organization. Annual series. “Industrial Property Statistics.” Geneva.